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EXPLORATORY FIELD INVESTIGATION OF GROUND PENETRATION BY AERIAL PLANTING-DARTS AND SUBSEQUENT GERMINANT SURVIVAL

by

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EXPLORATORY FIELD INVESTIGATION OF GROUND PENETRATION BY AERIAL PLANTING-DARTS AND SUBSEQUENT GERMINANT SURVIVAL

ÉTUDES PRÉLIMINAIRES SUR LE TERRAIN DE LA PÉNÉTRATION ET DE LA SURVIE ULTÉRIEURE DE SEMIS EN TUBES (DARDS) PLANTÉS PAR AÉRONEF

by/par

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ABSTRACT

The ability of aerial planting-darts to penetrate the ground and the subsequent survival of germinants have been investigated through air-drop tests conducted at various dissimilar sites.

The results indicate that there is a range of penetration within which darts may be considered as suitable candidates for the establishment of seedlings. Given some discretion in the selection of sites for aerial planting, it now appears reasonable to expect at least half the darts to achieve penetration within this range. The ultimate success, in terms of darts occupied by at least one surviving seedling, will then depend upon additional factors such as the depth of the mineral soil horizon below the ground surface, the presence of vegetation, the time of year and the prevailing weather.

Vigorous seedlings have been established by air-drops at some sites. Overall success rates are not, as yet, adequate, but the results have demonstrated the potential of the aerial planting technique and indicated some of the most promising avenues for further investigation and testing.

RÉSUMÉ

Des essais de plantation aérienne ont été effectués en plusieurs endroits différents afin d'étudier la pénétration et la survie ultérieure de semis en tubes (dards).

Les résultats obtenus indiquent qu'il existe une certaine zone de pénétration dans laquelle les dards pourraient s'avérer appropriés à l'établissement de semis. Si les endroits pour la plantation aérienne sont choisis avec discernement, on peut raisonnablement prévoir qu'au moins la moitié des dards se trouveront dans cette zone. Le succès ultime de l'opération, déterminé par le nombre de dards donnant naissance à au moins un plant viable, sera fonction d'autres facteurs comme la profondeur de l'horizon minéralisé, la présence de végétation, le moment de l'année et les conditions météorologiques.

Des semis vigoureux ont pu être établis par plantation aérienne dans certains endroits. Le taux de succès global n'est pas encore approprié, mais les résultats obtenus ont démontré de bonnes possibilités pour la plantation aérienne et ont indiqué certaines des approches les plus prometteuses pour la poursuite de la recherche et des essais.

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1.0 Introduction

An aerial planting concept intended for forestry applications has been described in Reference 1 and progress in its development as a system outlined. The key element in the system is a small dart*, fabricated from paper and plastics, which serves as the means for conveying one or more seeds of the selected tree species to the ground in such a way as to enhance prospects for germination and survival. A small quantity of growth medium within the dart provides the seed or seeds with an immediate environment which has favourable properties, while the ability of the dart to penetrate the ground surface positions the emerging roots deep within the soil. This may be a significant advantage where mineral soil is overlain by humus or debris, as is often the case, or where the surface layers rapidly lose moisture.

While the development of various other components of the system, such as dart-dispensers and accurate navigational guidance aids for the helicopter used as the planting vehicle, has occupied a prominent place in the program, the accumulation of field test data on the performance of darts after impact with the ground has been regarded from the outset as a priority concern. For this reason the work carried out during 1982 and here reported, has been directed almost exclusively to this aspect of the program.

2.0 Objectives

In evaluating dart performance after impact with the ground it has been convenient to identify two major objectives:

a) to acquire field test data, at several dissimilar sites, relating dart penetration to site characteristics,

b) to establish, to the extent possible, the influence of each of the most significant factors governing seed germination and subsequent seedling survival.

* Patented

Depth of penetration with respect to the mineral soil horizon is likely to be one of these factors, but others include:

- moisture (either present or available from precipitation);
- heat (and the degree of exposure to or protection from it);
- competition from other plants;
- drop timing (with respect to the available growing season);
- pest activities.

In addition to addressing these major objectives, the 1982 field test program provided the following subsidiary opportunities:

c) to validate the dart materials and design, particularly the functioning of the sealing-tape with its water-soluble adhesive,

d) to gain experience with a preferred candidate growth medium,

e) to develop dart assembly, filling and sealing procedures suitable for meeting field test requirements (thousands).

3.0 Test Sites

For convenience in developing test procedures and to facilitate frequent monitoring, sites close to Ottawa were advantageous. Sites more representative of large, commercially-harvested, forest areas are further from Ottawa and less amenable to frequent visits. As a compromise, the 1982 field test program was accommodated within four localities. One of these (Kemptville) is very close to Ottawa, two others (Petawawa and Mont Laurier) are within daily commuting range by helicopter and the fourth (Aubrey Falls) required a sustained operation in the field of several days duration.

The characteristics of the sites made available are summarised in Table I.

Several of the sites in the Aubrey Falls area referred to in this report were also included in a short program carried out jointly in that area with staff of the Great Lakes Forest Research Centre of the Canadian Forestry Service, who made additional observations and measurements on the ground.

4.0 Equipment and Procedures

4.1 Dart

The dart configuration used in this program is illustrated in Figure 1. Darts dropped at the various sites differed from one another only in the quantity and composition of the contents. The average empty weight of each dart, comprising the paper cone, heavy, shaped, plastic nose-cap and interior plug, amounted to 11.8 g. The weight of the contents increased from 4.5 to 6 g as the quantity of soil mix loaded was increased during the program.

The basic soil mix chosen was one which had demonstrated favourable characteristics during a preceding program of greenhouse tests carried out at the University of Toronto. Its composition is given in Table II, together with other constituents of the dart "payload". Table II also indicates the loading sequence followed during the program and identifies notable variations.

The perlite or vermiculite layer, added as the final step in the loading schedule, served to fill the cavity in the tail-cone of the dart with a light-weight material and was intended to prevent significant disturbance of the contents during handling prior to use in the field.

The compressed peat pellets were introduced as a measure to increase the effective volume of the dart contents after impact. The pellets expand after absorbing water. It was also thought that this material might have

a favourable effect in terms of moisture retention during the germination period.

To prevent premature germination in darts being stored for several weeks before the field tests, unstratified seeds were used and the basic soil-mix was oven-dried to reduce the moisture content to less than 5 per cent.

Figure 2(a) is a photograph of darts used in the program. In most cases a light-weight, plastic streamer was attached, as shown, to improve conspicuity on the ground. The transverse markings on the other dart are 1 cm apart.

Figure 2(b) illustrates the normal paths followed by the escaping radicle and lateral roots in darts of this type.

Figure 2(c) is a photograph of a typical seedling from darts identical with those used in the field tests, but in this case grown in a sand-filled pot under artificial light.

4.2 Dispenser

In meeting the major objectives of the 1982 program, there was no necessity to distribute darts along a lengthy flight-path, which would unnecessarily increase the difficulty of the subsequent search and ground monitoring. Instead, the procedure adopted required the helicopter to hover above selected target sites. Clusters of darts, typically 25, 50, 75 or 100 in number, were then released. The dispersion normally present automatically provided a random sampling of the site over an area with a typical dimension of, perhaps, 20 ft.

The dispenser constructed for this task was, thus, quite simple, as shown in Figure 3. It consists of a box in which up to 104 darts may be accommodated. The darts are oriented vertically and separated from each other by a grid of partitions. Hinged doors under each row of darts are actuated simultaneously from the cockpit by a lever and cable system.

4.3 Flight Procedures

To facilitate comparisons, a nominal drop height of 300 ft above the target site was used for all field tests. Coloured boards were used to designate the aiming point and the helicopter was positioned with the assistance of instructions transmitted by radio from a ground observer located opposite the target and several hundred feet to one side. With some practice, this procedure resulted in acceptably small errors.

Following each drop, darts were located and marked using smaller boards (floor tiles) and the resulting drop pattern was normally photographed from the helicopter using a vertically-oriented, 70 mm camera (Fig. 4).

4.4 Ground Monitoring

As a less temporary measure, the flat marker at each dart was replaced by a stick with flagging-tape. A plastic plant-marker giving the drop number and date was also placed next to each dart for use in identifying photographs. Observations of dart penetration and inclination were recorded immediately after each drop. Subsequently, visits were made to each site during the remainder of the growing season to observe and photograph emerging and developing seedlings and to record changes in the characteristics of the sites within the same period.

Records of precipitation and of maximum and minimum daily temperatures for the season were obtained from the nearest observing stations. At Kemptville such measurements are made within 1 mile of the drop sites. At Petawawa the observing station is approximately 3 miles from the drop site. In the case of Mt. Laurier the nearest observing station is 16 miles away, while for sites in the Aubrey Falls area the distance to the nearest observing station at Peshu Lake is between 13 and 17 miles.

These records are presented in Figures 5 to 8. The dates on which various drops were made are also indicated at the bottom of these figures.

5.0 Results

5.1 Penetration of the Ground

Figures 9 to 13 present the observations of penetration obtained at nine sites having the characteristics summarized in Table I. Since the observable parameter is the axial length of fin remaining exposed above the ground surface, penetration is expressed in terms of "fin exposure". The corresponding submerged length is illustrated by the transverse lines in Figure 2(a).

The penetration achieved at the three Kemptville sites, used for initial testing, is apparent in Figure 9. At Site (1) (see also Fig. 14) only 12 per cent of the darts penetrated to the preferred range with a fin exposure of between 0 and 2 cm. Another 34 per cent fell in the range between 2 and 4 cm, while 18 per cent were in the range 4 to 5 cm. The remainder, 36 per cent, had totally inadequate penetration, generally as a result of striking obstructions (stones) on or below the surface. The terms "preferred", "shallow", "marginal" etc. associated with various ranges of fin exposure are somewhat arbitrary, since they pre-suppose a relationship between penetration and the prospects for seed germination and seedling survival. Subsequent observations, however, discussed in Paragraph 5.2, provide broad justification for the terminology adopted.

The results obtained at Sites (2) (see also Fig. 15) and (3) (see also Fig. 16) differ markedly from those at Site (1) Both of these sites were reverting to heavy vegetation, whereas Site (1) had no vegetation when the darts were dropped. The presence of vegetation increases the difficulty in locating darts and some remain undiscovered. Consequently the results are shown as percentages both of the number of darts located and and of the number of darts dropped.

Comparing, for the three sites, the results based on the former criterion, some marked differences are apparent. At Site (2), for example, the percentage of darts with inadequate penetration is greatly reduced, the distribution strongly favouring penetration in the preferred range. At Site (3), where the surface characteristics are less uniform, the distribution reflects this non-uniformity, with some darts recovered from below the surface in soft areas.

From experience in searching for darts in field tests, particularly those carried out near Mont Laurier and Aubrey Falls, where streamers were used, it is now clear that many darts penetrate far enough that any portion of the fins remaining above the soil surface may be easily concealed by the smaller plants or debris. Without streamers these darts are not always found, yet some may well be good candidates for the establishment of seedlings. Percentages based on the number of darts dropped are regarded, therefore, as unduly pessimistic, since all undiscovered darts are thereby rejected. More significance is attached to percentages based on the number located.

Figure 10 shows the results obtained with a much larger sample of darts at Petawawa, Site (3) (see also Fig. 18).

The distribution resembles that for Site (2) at Kemptville, but has a less pronounced peak in the preferred penetration range and a greater percentage of darts with inadequate penetration. These differences are probably attributable to the much greater quantity of surface litter present at the Petawawa site, as is apparent from a comparison of the photographs shown in Figures 15 and 18.

It is interesting to note that 58 per cent of the darts located at Petawawa, Site (3) are within the 0 to 4 cm range of fin exposure. This compares with 76 per cent in the same range at Kemptville Site (2). Both sites have relatively uniform surface characteristics.

Figure 11 shows the results for two sites near Mont Laurier, P.Q. These two sites differ from those selected at Kemptville and Petawawa through the presence of considerable organic material. At Site (2) this had been broken up to some extent by scarification and mixed with fragments of brush and the underlying sand. At Site (3) the organic layer has remained undisturbed since the area was logged several years ago. Photographs of the two sites appear in Figures 22 and 23.

The outstanding characteristic of the distributions of penetration shown in Figure 11 is their relatively symmetrical form, approximating a normal distribution with the peak in each case in the 0 to 2 cm fin exposure range. Almost the same number of darts penetrated to submerge the fins from 0 to 2 cm below the surface as came to rest with 2 to 4 cm fin exposure. Provided that restraints due to the surrounding material are not sufficient to prevent at least partial opening of the fins with moisture absorption after impact, such sub-surface darts may offer additional prospects for seedling establishment.

Losses due to surface obstructions were 20 and 10 per cent respectively at Sites (2) and (3). If the fin exposure range of significance for such sites could be extended to 2 cm below the surface, 63 per cent of the darts at Site (2) and 75 per cent at Site (3) would be candidates for subsequent seedling establishment.

In discussing the results so far, penetration has been evaluated with respect to the surface of the ground. At Mont Laurier, Site (3), the mineral soil horizon is typically eight centimetres below the ground surface, as shown by the cross-sectional photograph in Figure 23(c). At Mont Laurier, Site (2), the depth of the same horizon is variable as a result of scarification. Since the true potential for seedling establishment is more likely to be associated with penetration of the mineral soil horizon than of the ground surface, the penetration data presented for the Mont Laurier sites provide a less direct indication of this potential than those at Kemptville

and Petawawa, where the depth of the mineral soil horizon at the selected sites is considerably smaller. With this reservation, Figures 9, 10 and 11 give a first indication of the effect on dart penetration of a variety of surface and sub-surface characteristics.

For comparison, Figures 12 and 13 show penetration distributions obtained at three sites near Aubrey Falls, approximately 50 nautical miles south of Chapleau, Ontario. Site (F) (Figs. 12 and 24) is a small area subjected to a prescribed burn in 1981. The distribution has similarities with those obtained at Petawawa (Fig. 10) and Mont Laurier (Fig. 11). The site is sandy with an overlying, partially-burned, organic layer.

Site (C) (Figs. 13 and 27(a)) is an area which has been wind-rowed and scarified for ground planting.

Site (B) (Figs. 13 and 27(b)) is an unscarified, debris-covered area, which has remained untreated since being logged several years ago.

It is evident that the removal of some of the surface debris by windrowing and scarification greatly reduces the number of losses which occur when darts strike obstacles. The number of cases of inadequate penetration falls from 53 per cent at Site (B) to 22 per cent at Site (C). It also appears that the ground is softer at Site (C), possibly as a result of scarification.

In addition to penetration, dart inclination after impact is a parameter of some concern, since an excessive inclination could adversely affect the prospects for seedling establishment, as discussed further in Paragraph 5.2. It was noted, however, that instances of dart inclination greater than 45 deg. from vertical were rare and that large angles of inclination, when they did occur, were associated with inadequate penetration. Conversely, darts achieving substantial penetration of the ground were generally associated with inclination angles

much less than 45 deg. This qualitative observation is regarded as applicable to the results presented here for all values of fin exposure less than 4 cm.

5.2 Germination and Survival

5.2.1 Weather Records

Figures 5 to 8 show the timing of drops at the various field test sites in relation to daily temperature fluctuations and the occurrence of precipitation. For the 1982 growing season the following general comments may be relevant:

a) the maximum temperature records for Kemptville, Petawawa and Mont Laurier do not differ greatly from one another;

b) somewhat higher maximum temperatures occurred at Peshu Lake for appreciably longer periods, particularly in June and July, when daytime temperatures frequently exceeded 30°C;

c) these higher daytime temperatures at Peshu Lake were accompanied by lower temperatures at night;

d) precipitation amount was greatest and its frequency most uniform at Kemptville. Petawawa often experienced very light showers but also relatively dry periods of at least a week's duration in May, June, July and August;

e) precipitation at Mont Laurier was particularly scarce in July. At Peshu Lake lengthy dry periods occurred in June and July.

5.2.2. Qualitative Observations

Figure 14 illustrates the results of a drop made in late April at Kemptville, Site (1), where the bare soil was rapidly drying following the spring thaw. In this figure, photographs (a) and (b) indicate the area sampled by a drop and the method of marking and labelling a typical sealed dart immediately after impact. Photograph (c) shows another typical

dart, with the fins unsealed, 13 days after the drop and (d) shows the same dart eight weeks after the drop. In the intervening period the paper has disintegrated at the soil surface, allowing the exposed part of the cone to become detached and showing a young Jack Pine seedling with developed cotyledons. The photographs also illustrate the amount of weed growth in the same period.

Figures 15, 16 and 17 similarly exemplify the results of drops at Sites (2) and (3) at Kemptville. Unlike Site (1), which was cultivated for other purposes at the end of June, Sites (2) and (3) remained available for monitoring throughout the year. The heavy growth of vegetation occurring at both sites is notable. Figures 15(c) and (d) and 16(c) and (d) show the germination and development of Jack Pine seedlings in two darts chosen as examples. In Figure 16(d) the seedling appears to be thriving with its roots below a clump of moss, a situation which was repeated a number of times during the program. The four examples shown in Figure 17, all photographed in mid-October, more than five months after being dropped, were selected to illustrate the survival of seedlings despite considerable variations in dart inclination and penetration on impact. In this figure the development of all seedlings is approximately the same although the darts in (a) and (c) (upper cone missing) have an inclination close to 45 deg. and the dart in (d) has 4 cm of fin exposed. The dart in (b) penetrated vertically leaving just over 2 cm of fin exposed.

Figures 18 to 21 refer to Site (3) at Petawawa. The appearance of the site in early May and late October is shown in Figure 18. The way in which the littered surface has been penetrated by several darts is evident in Figure 18(b). The germination and development of Jack Pine seedlings in two darts during the season are illustrated in Figure 19 while Figure 20 presents several other examples photographed in September or October. All of these seedlings are vigorous in appearance. Figure 21 shows two examples of White Pine seedlings resulting from drops made at this site. Unlike Kemptville, very little

vegetation appeared at this site during 1982.

Figures 22 and 23 illustrate the field tests made near Mont Laurier. Differences between the two sites are apparent in the aerial and ground photographs of the drop zone. The undisturbed organic layer of Site (3), referred to in Paragraph 5.1 and shown in Figures 23(c), is approximately 8 cm deep at this point. Figures 22(c) and (d) and Figures 23(d) present examples of seedlings surviving at the two sites in late October. The poor growth exhibited at these two sites is probably attributable to several factors, of which the lateness of the drops (mid-June to early July), subsequent dry, hot weather (see Fig. 7) and, at Site (3) in particular, the relatively deep organic layer, are thought to be the most significant.

The regeneration of forest areas destroyed by fire has been regarded as one potential application of aerial planting of particular interest. The temporary suppression of surface vegetation and reduction in organic layer thickness which may result from fire could be favourable features. The presence of standing trunks, which could be an impediment to surface methods of replanting, may be less of a hindrance to an aerial technique; a consideration if rapid coverage of a large area is required.

For these reasons an early opportunity to carry out drops over burned areas was sought. Such an opportunity arose during the field tests near Aubrey Falls, where it was possible to make drops at the sites of two prescribed burns. One of these, Site (F) (Fig. 24), was burned in 1981, the other, Site (A) (Fig. 25), in 1982, shortly before the field tests. The difference in vegetation at the two sites at the time of the drops may be seen by comparing the photographs in these two figures.

The two sites were revisited on August 26, 1982, approximately eight weeks after the drops. Examples of darts found with surviving Jack Pine seedlings at these sites are shown in Figures 24(d) and 25(d). The photographs in Figure 26 were taken on the same date in August, but show Jack Pine

seedlings growing in darts which were planted manually at Site (A) by staff of the Great Lakes Forest Research Centre. The manual plantings were made 10 days after the air drops at Site (A). They differ from the air-dropped darts in their uniformity of penetration. All of the 100 darts planted manually at Site (A), to serve as controls, were intentionally given 1 cm fin exposure after surface material had been brushed clear at each proposed dart position to reveal the mineral soil. Although the depth of such material was not great and some of the debris returned after planting, the seedlings grown in these manually-planted darts were markedly more advanced and vigorous than those in the air-dropped darts.

Figure 27 shows several other sites involved in the joint program referred to in Paragraph 3.0. The penetration measurements from Sites (C) and (B) shown in Figure 13 are the only results from that program reported here. Germination and survival at these sites was generally poor.

5.2.3 Quantitative Observations

In Figures 28 to 31 an attempt is made to present in quantitative terms the results of 1982 field tests at the four selected localities.

In each figure the weather record is represented by the maximum daily temperature and the cumulative precipitation derived from Figures 5 to 8. Above these, the observations of germination and survival, made during the remainder of the season following each drop, are shown as time histories. The significant parameter is taken to be the percentage of darts occupied by one or more seedlings. In calculating this percentage, only darts penetrating within the range (fin exposure from 0 to 4 cm) currently regarded as providing candidacy for seedling establishment are considered. This convention is of some advantage in utilizing separately-acquired penetration and growth data to predict overall success rate, which is the product of the percentage of darts occupied and the fraction of darts falling within the candidate penetration range.

For the air drops made at Kemptville, quantitative data points are plotted in Figure 28. Observations continued at Sites (2) and (3), but not Site (1), until late October. The relatively small change in percentages of darts occupied by seedlings during the preceding four months is noteworthy. Although only qualitative observations were made during the period when germination was taking place, it is assumed that the tentative interpolations shown by dashed lines would bear some resemblance to the numerical facts.

Of particular interest in this figure is the value (84 per cent) achieved at Site (1) eight weeks after the drop and just before the site was reclaimed for other uses. If the subsequent mortality at this site had followed a trend similar to those exhibited at Sites (2) and (3), more than 75 per cent of the candidate darts would have been occupied by seedlings in late October.

At Petawawa, despite some individual cases of darts with exceptionally vigorous seedlings, as illustrated in Figures 19 to 21, the percentages of occupied darts were lower than those at Kemptville. Figure 29 shows the results obtained for both Jack Pine and White Pine at this site. Referring to the cumulative precipitation record, it is evident that the drops were made during a comparatively dry period. Germination was probably accelerated by considerable precipitation about three weeks later. A dry period of nine days duration followed, after which there was again significant precipitation before further dry periods in June, July and August. Some mortality shortly after germination was observed and hence the curves are thought to have peaked in a manner somewhat as shown. For White Pine, subsequent mortality during the summer months was observed to be greater than that for Jack Pine.

As already indicated in Paragraph 5.2.1, the combination of late drop dates, dry, hot weather and a deep organic layer contributed, it is thought, to the poor record of growth at Mont Laurier, shown in Figure 30. The sites were revisited,

however, on July 14 when germination may well have been near its peak at Site (2) and, for one drop, at Site (3). A subsequent visit, on July 30, provided quantitative evidence of mortality, most pronounced at Site (3), which took place within this period. Increased rainfall in August and early September probably came too late to prevent most of the additional mortality, occurring during the remainder of the season, as observed in late October.

Figure 31 shows the results obtained in the Aubrey Falls area at Site (F), the 1981 prescribed burn. Also shown, for comparison, are the results observed at the control plots at Site (A) (1982 burn) where darts were planted manually with 1 cm fin exposure above the mineral soil horizon, as noted in Paragraph 5.2.2.

From the accompanying weather records it will be seen that the drop took place during a dry period in which, on two days, temperatures reached 30°C or more. The manual planting at Site (A) was made ten days later during a cooler period in which there was some rainfall. There followed another dry period of at least eleven days duration when temperatures again exceeded 30°C for several successive days. Significant rainfall then occurred for the next ten days and again every few days after another eight-day dry spell in the second half of July. Temperatures rose above 30°C on numerous occasions throughout July and early August.

Two quantitative observations, one on July 22 and the other on August 26 show that 15 per cent of the candidate darts at Site (F) were occupied by at least one seedling each on these two dates.

The corresponding value on August 26 for the manually-planted darts at Site (A) is 84 per cent. Furthermore, as illustrated by the examples in Figure 26, there were several seedlings in each of the manually-planted darts. The apparently superior performance of these darts is somewhat exaggerated by the fact that, inadvertently, the batch used contained six Jack

Pine seeds per dart as compared with three seeds in each of the air-dropped darts. Without this factor, however, the difference in performance would still be striking.

In explaining this difference it is logical to suppose that penetration of the mineral soil horizon is the most significant factor and that the substantial, uniform depth, reached by the manually-planted darts, established for them a clear advantage as compared with the more random and, in this instance, possibly inadequate penetration of the same horizon by the air-dropped darts. The explanation is a tentative one, however, since the influence of other factors, such as the ten-day spacing between the air-drops and the manual-planting and differences in detail between Sites (A) and (F), are uncertain.

These results are considered to be of special interest for two reasons:

a) the 84 per cent level of success achieved in establishing seedlings by manually-planting darts in a burned area supports the view that such sites are particularly appropriate for further field testing;

b) they illustrate the potential for improvement in air-dropped dart performance.

In this latter regard, it is possible that performance, under similar conditions, would be improved by increasing the drop height or the weight of the darts to achieve somewhat greater penetration of the ground surface and hence of the underlying mineral soil horizon. Increasing the penetration by one, or possibly two, centimetres, in this case resulting in a corresponding downward shift of the distribution shown in Figure 12, could be advantageous. Alternatively, a more favourable result may be attainable by carrying out air-drops somewhat earlier in the year, when residual moisture is more likely to be found above the mineral soil horizon. An even better possibility for finding and making use of such moisture, during

the short period of vulnerability before a primary root is in contact with mineral soil, may arise with air-drops carried out in the late Fall. With this choice of season, the darts would remain in a dormant condition until the following Spring.

6.0 Concluding Remarks

The exploratory field tests which have been described in the preceding paragraphs have provided opportunities for both qualitative and quantitative observations of aerial planting-darts in a variety of situations. Measurements of penetration of the ground surface by darts dropped at dissimilar sites have given a first indication of the magnitude of the variations in penetration to be expected and of the interference caused by stones, debris or other obstructions. Where the mineral soil horizon is close to the ground surface, as at the Kemptville sites, seedlings have been established in darts having between 0 and 4 cm of fin length exposed after impact and with inclinations of up to 45 deg. from the vertical.

Where the mineral soil horizon is separated from the ground surface by a layer of organic material, maintaining the greatest possible penetration of this horizon by minimizing the fin length exposed above the ground surface is evidently advantageous. Complete submergence of the fins below an ill-defined surface may lead to seedling establishment provided that the surrounding material does not prevent partial opening of the fins. Since the paper cone is just under seven cm in length and its forward end should preferably be in contact with mineral soil, darts are less likely to be effective in the presence of organic layers with a depth of more than about five cm. The field test results support this contention.

Seeds contained in air-dropped, planting-darts have successfully established seedlings (Jack Pine and White Pine) at various sites. Some particularly vigorous examples developed at Petawawa. At Kemptville, Jack Pine seedlings survived their first growing season in the presence of strong competition from site vegetation. The accompanying shade, by providing protection

from heat and dryness, appeared to offset the unfavourable effects of competition during this period. Seedlings were also successfully established in moss clumps penetrated by planting-darts.

In the Aubrey Falls area some seedlings were established at burned sites. Manual plantings at the same location gave particularly good results, indicating that burned areas should be the subject of special attention in any further air-drop tests.

Given some discretion in the selection of sites for aerial planting, it now appears reasonable to expect the penetration of at least half of the darts to be in the range required to make them suitable candidates for the establishment of seedlings. Achieving or exceeding this figure in typical operational areas, however, may require such measures as modest, but practical, increases in dart weight or drop height.

Thereafter, germination and survival will depend upon the more detailed characteristics of the site, the appropriateness of the timing and the weather. The first eight-week period appears to be the most critical from the standpoint of mortality. Hence, the probability of prolonged dryness or heat at this stage should be minimized by dropping as early as possible in the Spring. Alternatively, air-drops in the late Fall, before the ground becomes frozen, are worth consideration as a means of promoting early growth in the Spring.

Finally, the vulnerability of planting-darts to heat and dryness may be reducible either by improving their moisture-retention properties or by shortening the time required for developing roots to reach mineral soil. Water-absorbing polymers, used as additives to the growth medium, represent one possible approach to improved moisture retention and could well form part of a more thorough attempt to optimize growth medium constituents. Accelerated growth, through the use of biological agents would, if practical, shorten the time for primary root establishment in mineral soil.

During the course of the program very little interference from insects or rodents was observed. No significant adverse effects on seedling growth attributable to dart materials were apparent in preliminary laboratory tests or in the field and sealing-tape release performance was regarded as satisfactory. With some batches of completed darts it was necessary to re-seal the fins following premature release of the tape during storage. This problem is believed to be associated with humidity conditions at the time of tape application. Closer environmental control at this stage of dart manufacture is the most likely solution.

7.0 Acknowledgements

The author is indebted to numerous persons and organizations for permission to use the various test sites.

At Kemptville, thanks are due to Mr. A.J. Campbell, Superintendent, Mr. R. Klapprat and Mr. R.M. Van den Tillaart of the G.H. Ferguson Forest Station, Ontario Ministry of Natural Resources, for this and for other assistance provided. The cooperation of Dr. R.M. Newnham, Director, and other staff of the Petawawa National Forestry Institute, for facilitating tests at that station, is also gratefully acknowledged, as is that of the James MacLaren Company of Buckingham, P.Q. and the Département d'énergie et ressources, Quebec for making available sites in the neighbourhood of Mont Laurier.

In the Aubrey Falls area the test sites were located by staff of the Great Lakes Forest Research Centre (GLFRC) of the Canadian Forestry Service and were used with the permission of the Ontario Ministry of Natural Resources. The support provided in this area by Mr. L.F. Riley, Mr. J. Richenhaller, Mr. R. Folk and other GLFRC staff who participated in the joint program, is particularly appreciated, since the successful development of this new planting technique will continue to require a convergence of expertise both from within and outside the field of forestry.

In carrying out preliminary greenhouse tests at the University of Toronto to establish the suitability of various growth media under consideration, Dr. J.L. Farrar of A.D. Revill Associates also continued to provide valuable assistance.

Support of various kinds provided by colleagues is implicit in any project undertaken by the Flight Research Laboratory and the present example is no exception. The author wishes to acknowledge with thanks such support and to mention particularly that of Mr. Brian Usher and his staff, in the preparation of equipment, as well as that of Mr. Clark Isenor. In addition to his normal helicopter maintenance activities, the latter has spent many hours assisting the author in field work of a type with which both, at the outset, were equally unfamiliar, but which, hopefully, has not suffered unduly in consequence.

8.0 References

1. Wood, A.D. Brief Outline of an Aerial Planting Concept for Forestry Applications. National Research Council NRC NO. 19782, NAE Aeronautical Report LR-607, October 1981.

TABLE I

SUMMARY OF TEST-SITE CHARACTERISTICS

Kemptville, Ontario

Site (1) Bare, loamy-sand with numerous stones. Weed-controlled by cultivation Fall 1981.

Site (2) Natural hardwood, clear-cut 1979 and brush removed. Reverting to heavy vegetation. Well-drained, sandy-loam. Little organic material.

Site (3) Mixed conifer/hardwood, clear-cut 1980 and brush removed. Less uniform but otherwise similar to Site (2).

Petawawa, Ontario

Site (3) 30-year old Scots Pine Plantation, clear-cut 1981 and brush removed. Smaller litter remaining. Sprayed with 2-4-D July 1981.

Mont Laurier, Quebec

Site (2) Mixed conifer/hardwood, clear-cut and brush partially removed. Organic layer above sand. Surface materials, including remaining brush, inter-mixed by scarification.

Site (3) Primarily Black Spruce, clear-cut and brush mainly removed. Thick, undisturbed organic layer above sand. Reverting to coarse vegetation (e.g. blueberry).

Aubrey Falls Area (Mississagi River South of Chapleau, Ontario)

Site (F) Mixed conifer/hardwood subjected to prescribed burn 1981. Reverting to vegetation. Partially-burned organic layer above sand.

Sites also included in Joint GLFRC/NRC Program:

Site (A) similar to Site (F), but burned 1982.

Site (C) scarified area between wind-rows.

Site (B) unscarified area, clear-cut but brush remaining.

TABLE II

DART LOADING SCHEDULE

a)	Basic Soil Mix		2 ml	(Metromix 200:Silica Grit #40, 4:1 by vol.)
b)	J9 Compressed Peat Pellet		1.6 ml	(NPK % Content 12.6:6.6:15.6)
c)	Basic Soil Mix		4 ml	Kemptville (Jack Pine), Petawawa (White Pine)
		or	5 ml	Petawawa (Jack Pine)
		or	6 ml	Mont Laurier and Aubrey Falls
d)	Unstratified Seeds		2	Kemptville (Jack Pine), Petawawa and Mont Laurier (White Pine)
		or	3	Petawawa, Mont Laurier and Aubrey Falls (Jack Pine)
e)	Basic Soil Mix		0 ml	Kemptville and Petawawa
		or	1 ml	Mont Laurier and Aubrey Falls
f)	Perlite		2 ml	Kemptville and Petawawa
or g)	Vermiculite		2 ml	Mont Laurier and Aubrey Falls

Basic Soil Mix Oven-Dried to 5% Moisture Content

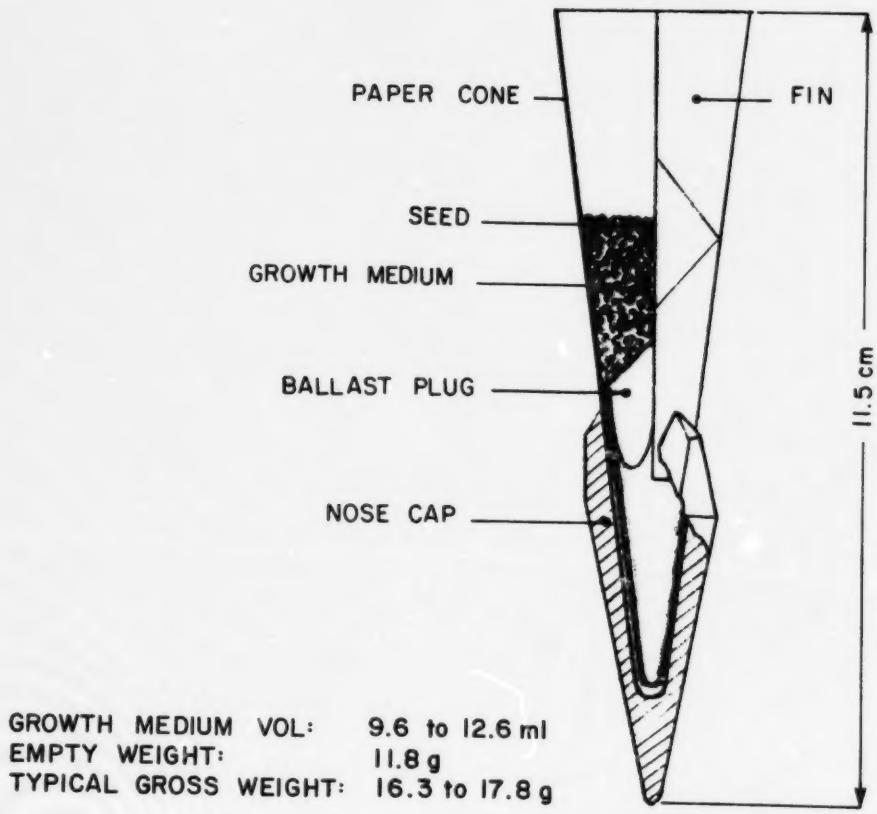
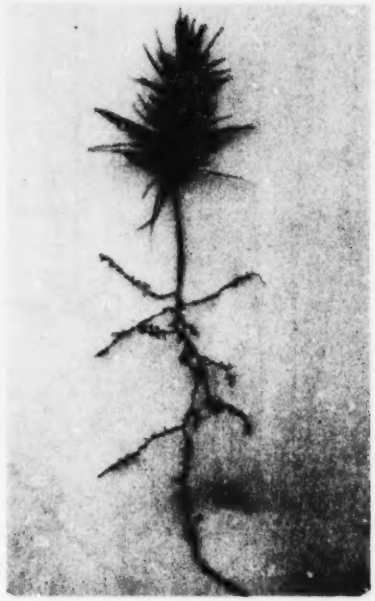


FIG. 1: AERIAL PLANTING-DART CONFIGURATION

(a) DARTS USED IN 1982 FIELD TESTS. (LEVELS OF FIN EXPOSURE IN CM INDICATED)

(b) LABORATORY JACK PINE TEST-DART LIFTED AFTER TWO MONTHS, ILLUSTRATING PAPER CONE DEGRADATION AND ESCAPING RADICLE



(c) LABORATORY JACK PINE TEST-DART LIFTED AFTER FOUR MONTHS, ILLUSTRATING TYPICAL ROOT CONFIGURATION

FIG. 2: PLANTING-DART CHARACTERISTICS. 1982 PROGRAM

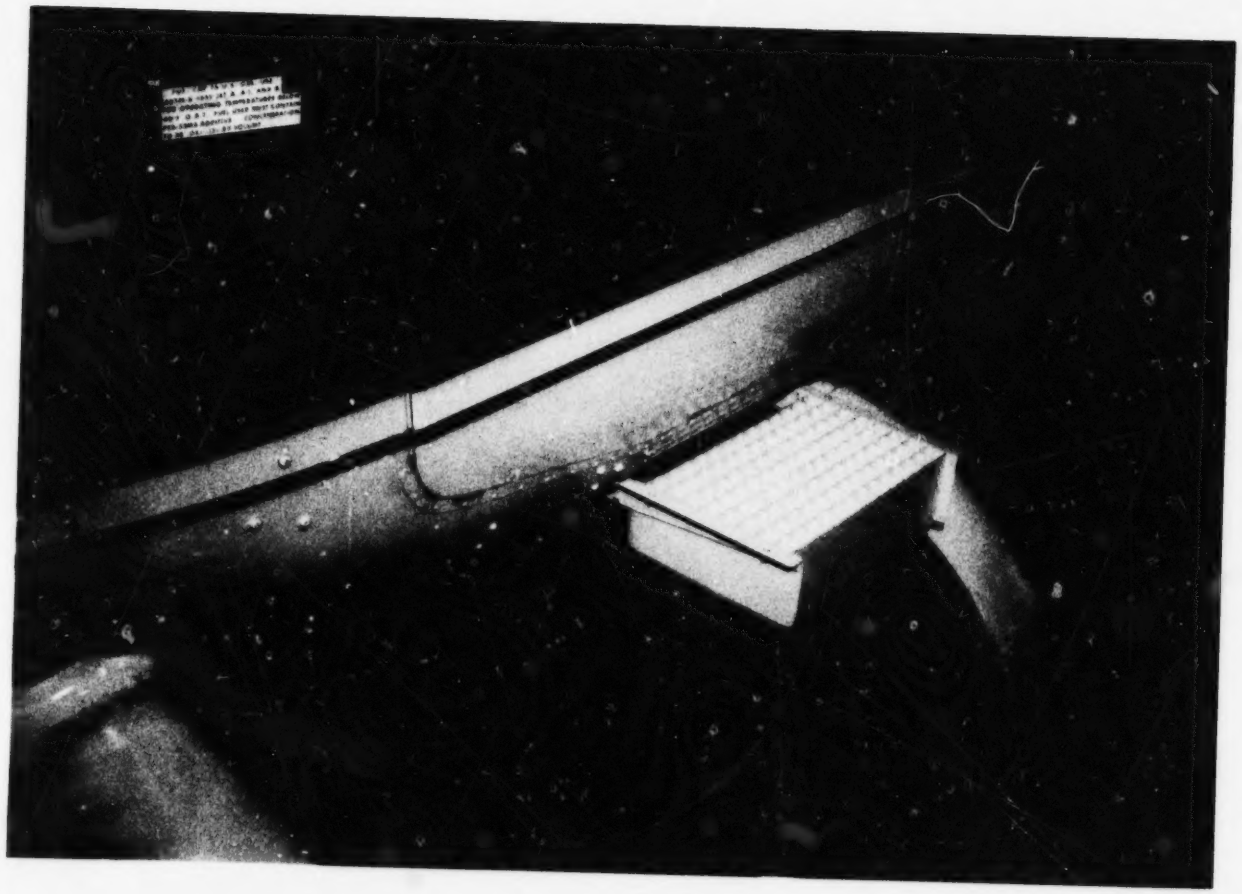


FIG. 3: DART-CLUSTER DISPENSER ON BELL 206A HELICOPTER

FIG. 4: AERIAL PHOTOGRAPH OF TYPICAL DROP PATTERN. (BURNED SITE)

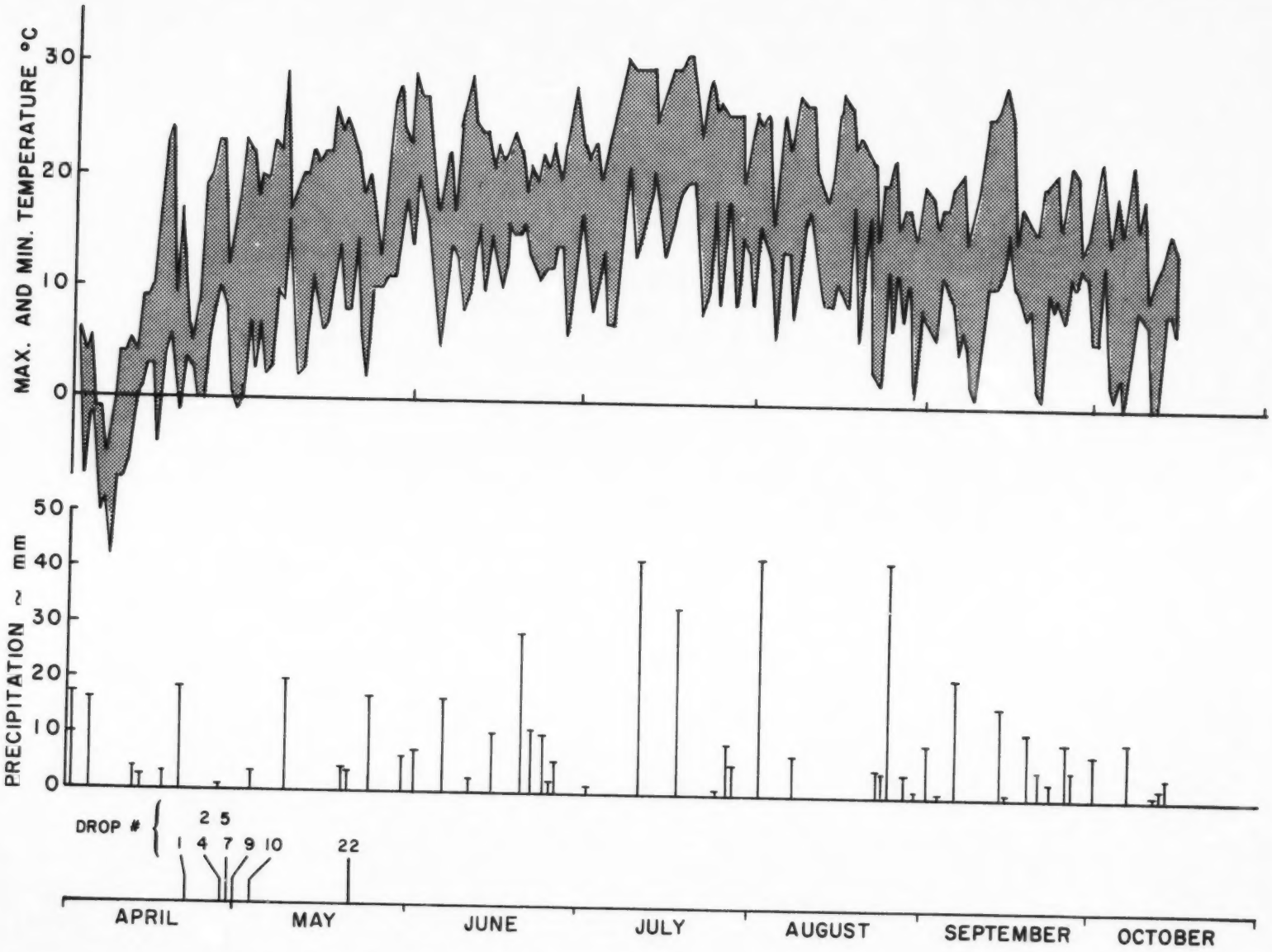


FIG. 5: KEMPTVILLE ~ MAX/MIN TEMPERATURES AND PRECIPITATION

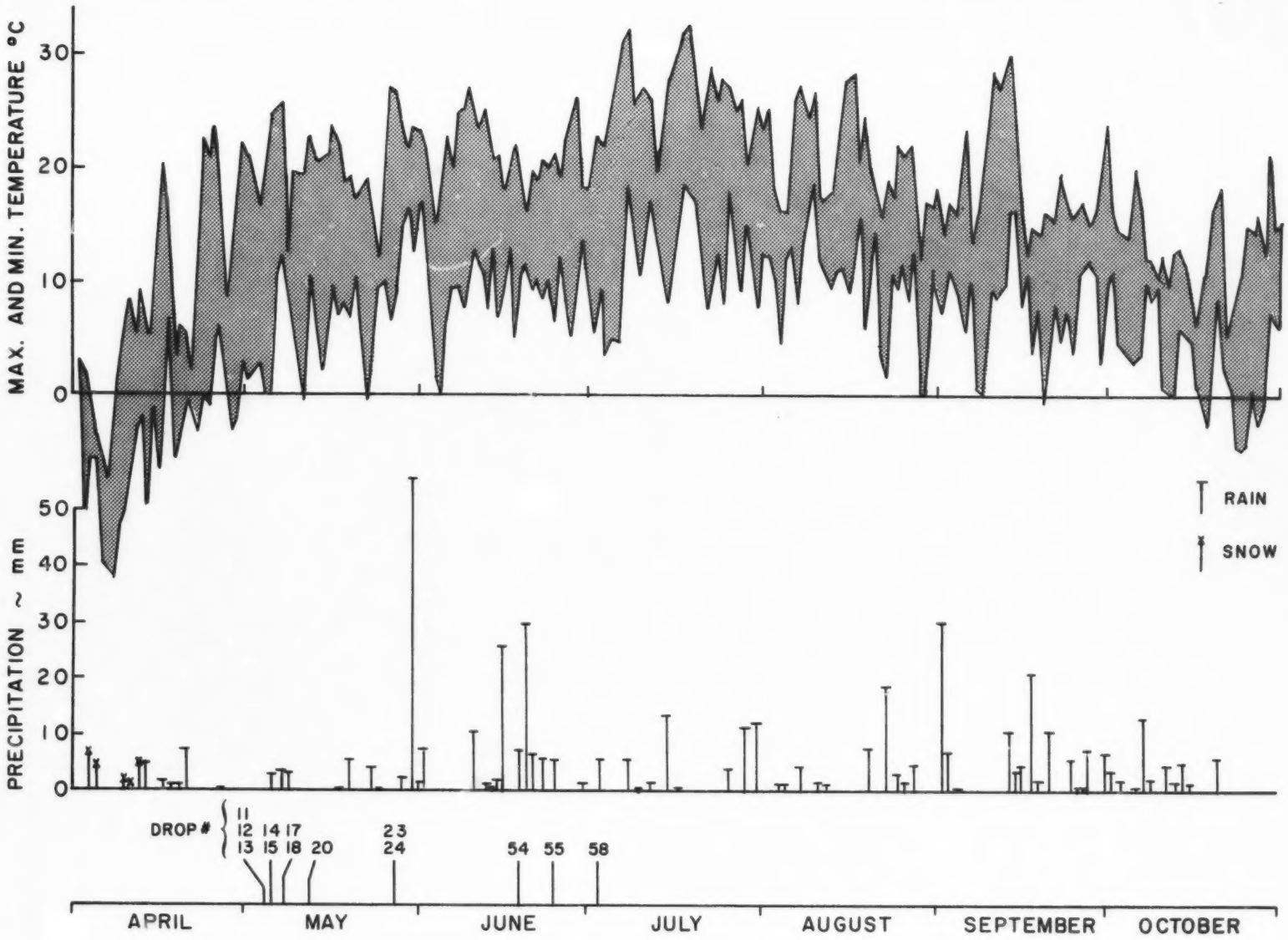


FIG. 6: PETAWAWA ~ MAX/MIN TEMPERATURES AND PRECIPITATION

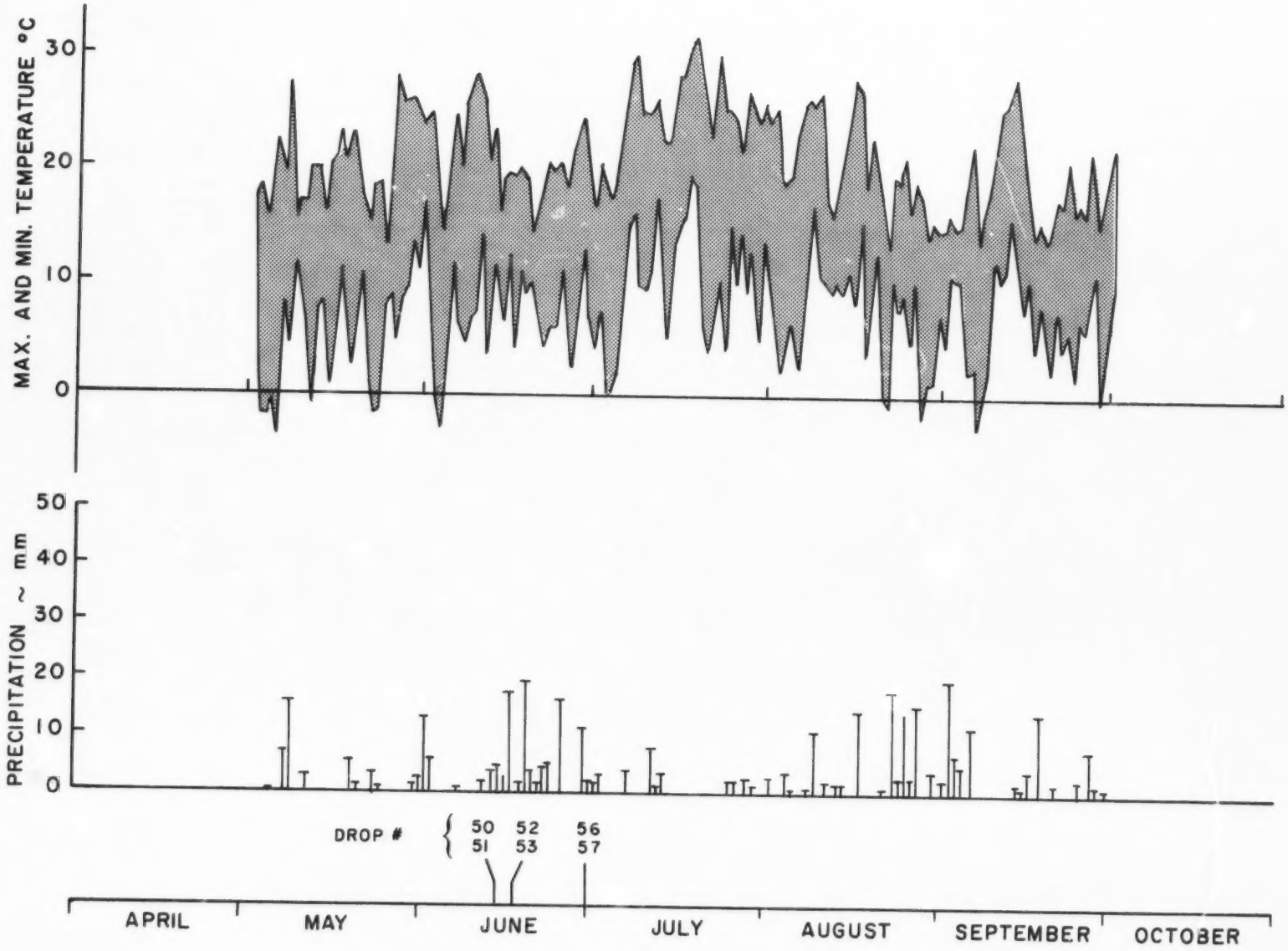


FIG. 7: MT. LAURIER ~ MAX/MIN TEMPERATURES AND PRECIPITATION

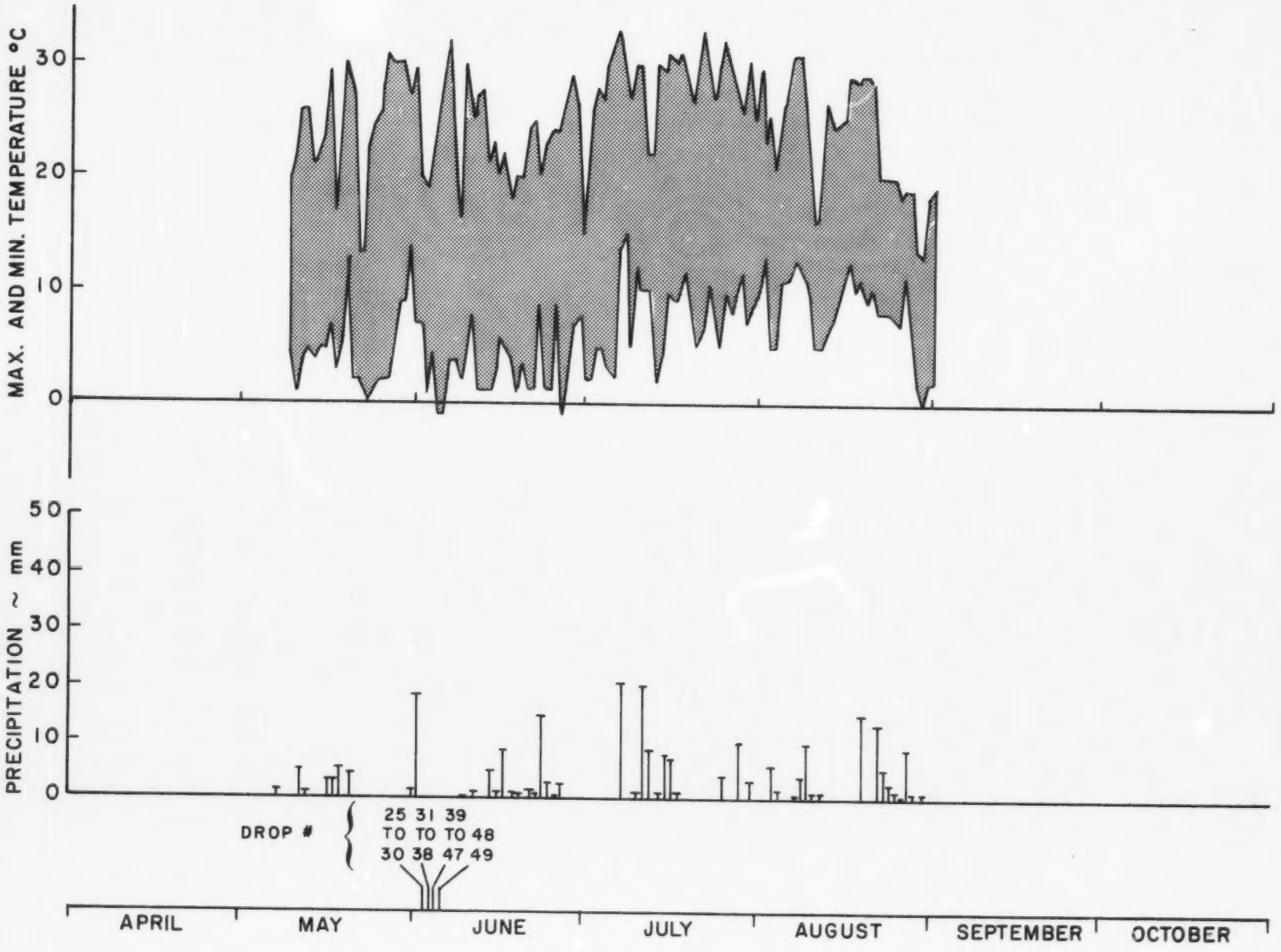


FIG. 8: PESHU LAKE ~ MAX/MIN TEMPERATURES AND PRECIPITATION

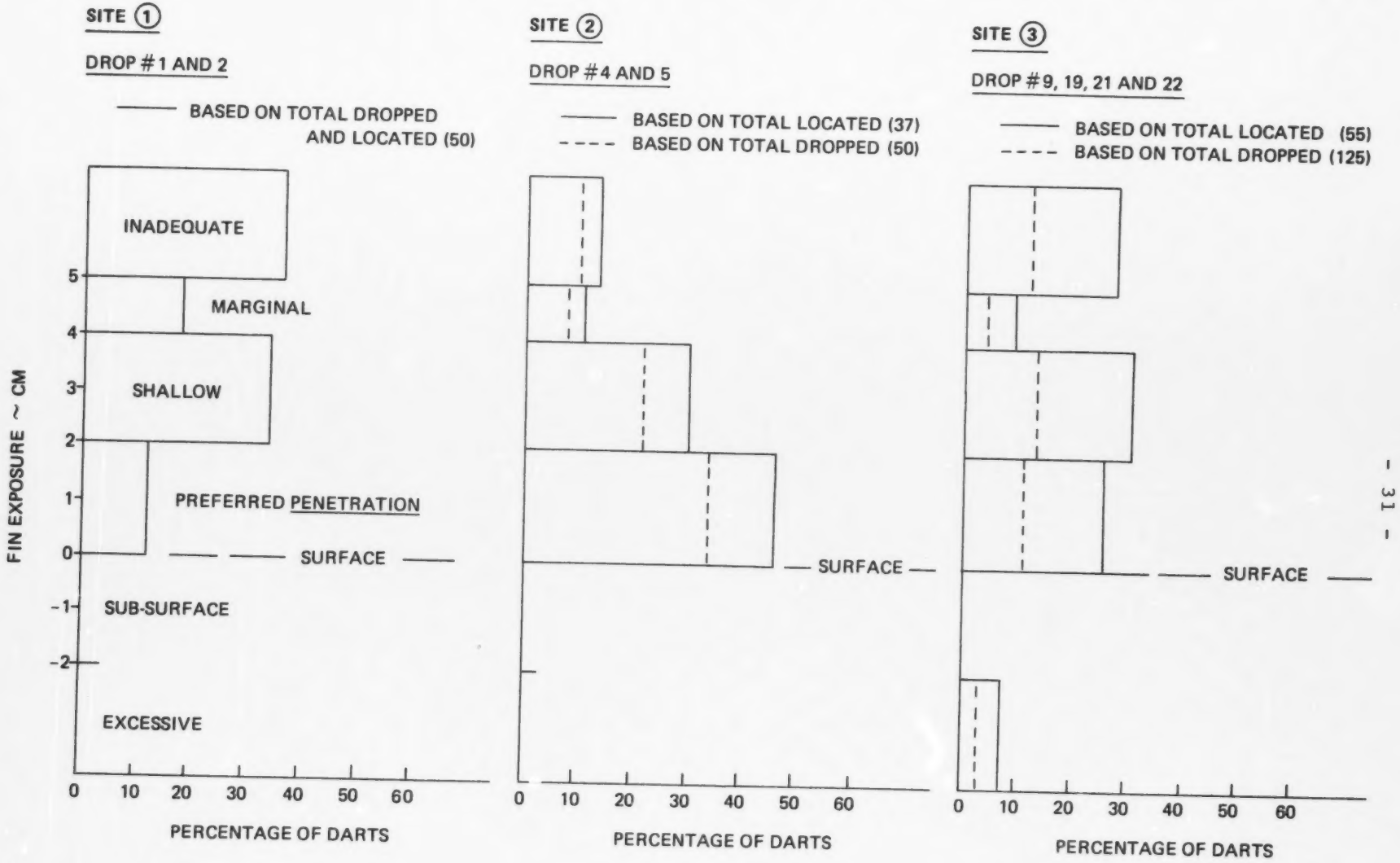


FIG. 9: KEMPTVILLE. COMPARISON OF PENETRATION (FIN EXPOSURE) AT THREE DISSIMILAR SITES

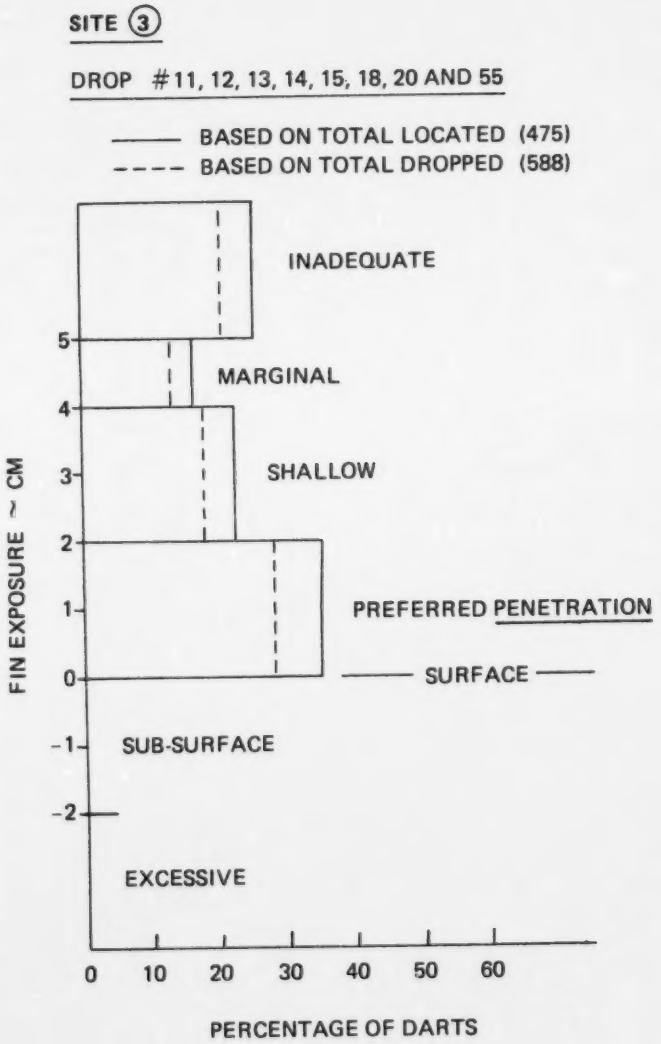


FIG. 10: PETAWAWA SITE 3. PENETRATION (FIN EXPOSURE) DISTRIBUTION

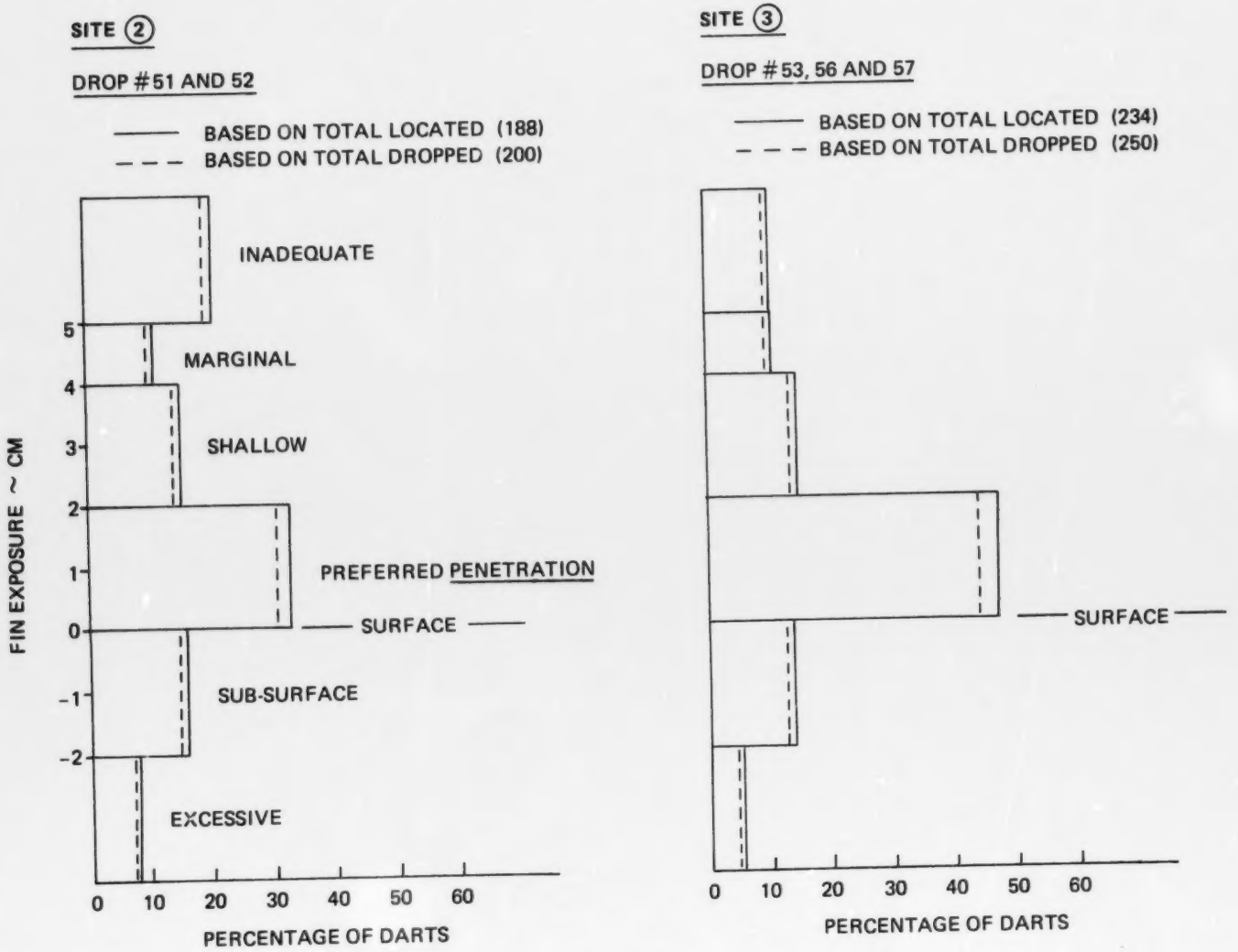


FIG. 11: MT. LAURIER. COMPARISON OF PENETRATION (FIN EXPOSURE) AT TWO DISSIMILAR SITES

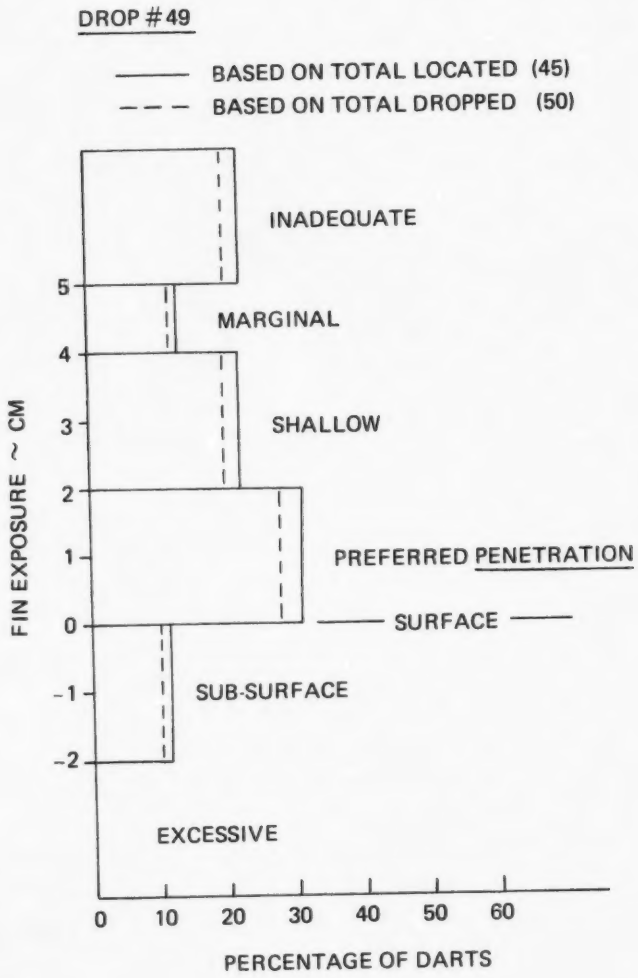


FIG. 12: AUBREY FALLS AREA, SITE Ⓕ (1981 BURN). PENETRATION (FIN EXPOSURE) DISTRIBUTION

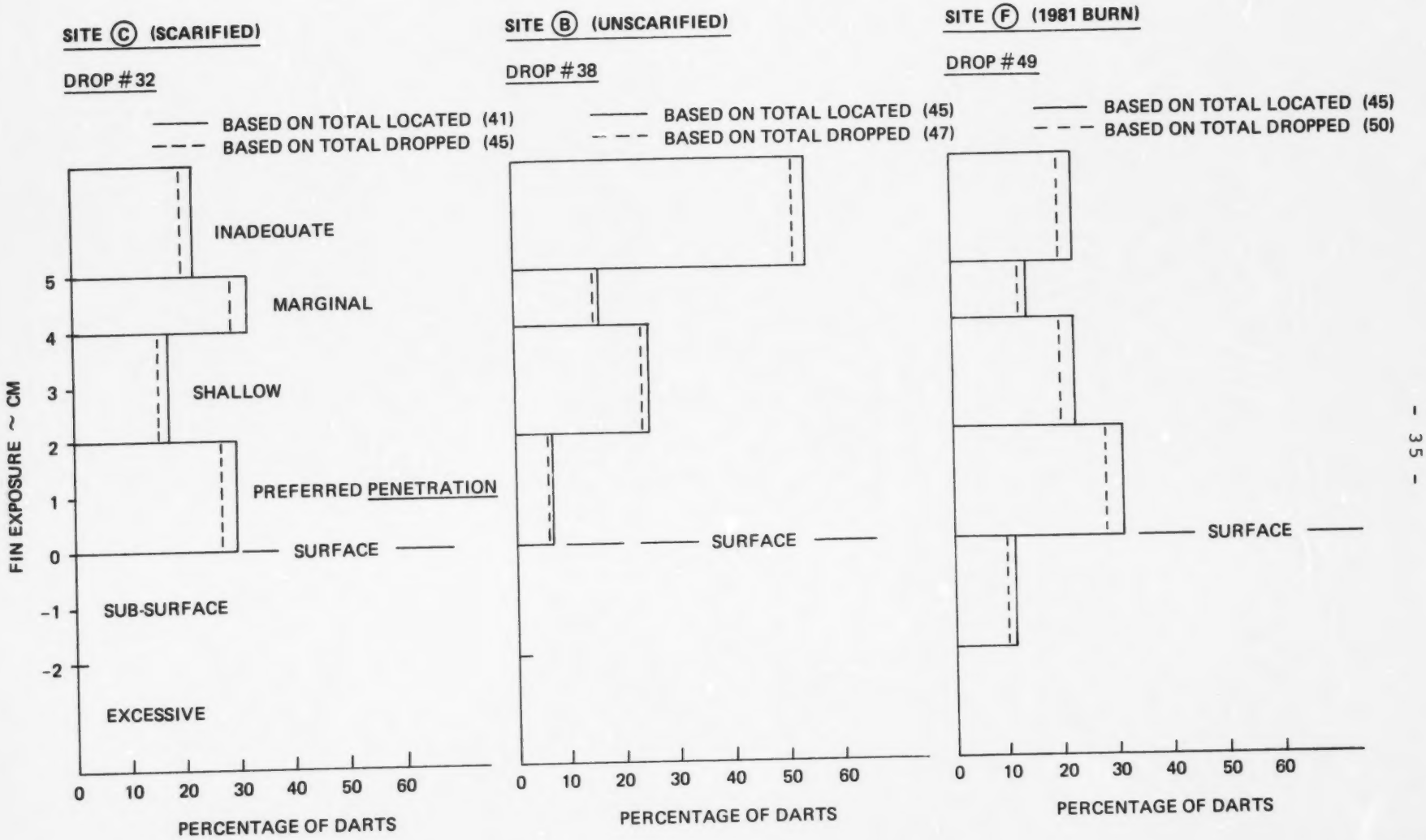
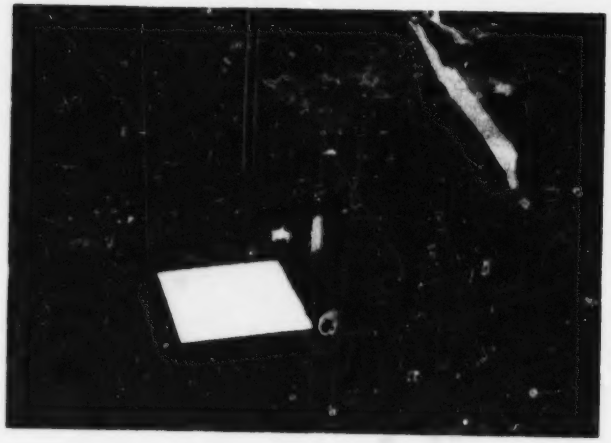
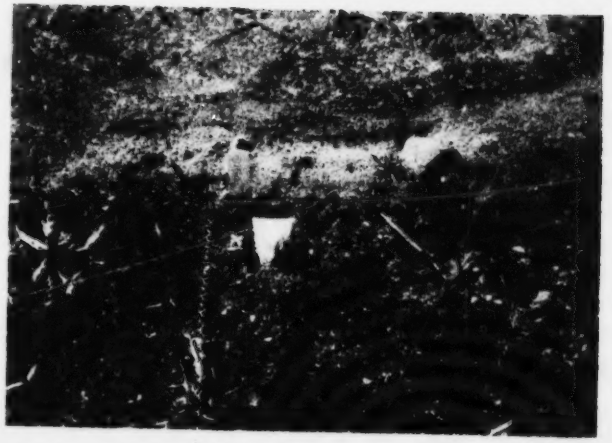


FIG. 13: AUBREY FALLS AREA. COMPARISON OF PENETRATION (FIN EXPOSURE) AT THREE DISSIMILAR SITES

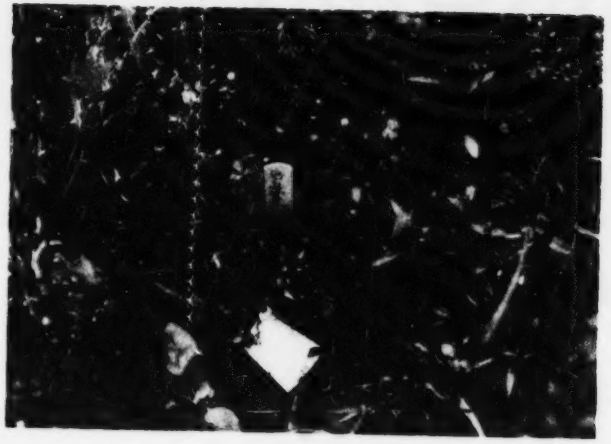
(a) DROP ZONE (PHOTO 28.4.82)



(b) TYPICAL DART (PHOTO 28.4.82)

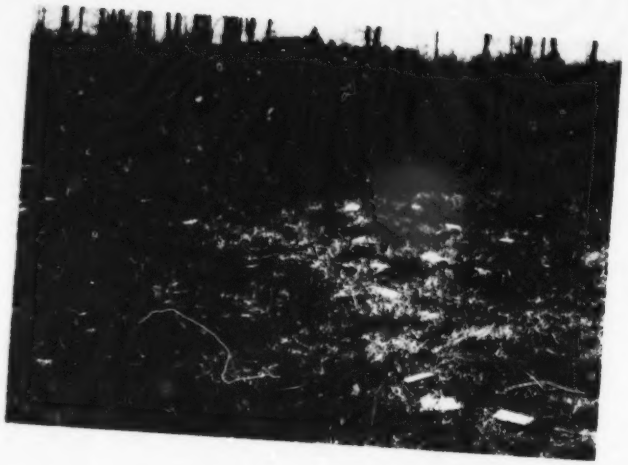


(c) TYPICAL DART (PHOTO 10.5.82)



(d) SAME DART AS (c) (PHOTO 23.6.82)

FIG. 14: KEMPTVILLE SITE ① . SITE CHARACTERISTICS AND TYPICAL DARTS.
DROP NO. 2 – DROP DATE: 28.4.82



(a) DROP NO. 5. DROP ZONE (PHOTO 29.4.82)

(b) DROP NO. 5. DROP ZONE (PHOTO 9.7.82)

(c) DROP NO. 4. DART B. (PHOTO 21.5.82)

(d) DROP NO. 4. DART B. (PHOTO 14.9.82)

FIG. 15: KEMPTVILLE SITE ②. SITE CHARACTERISTICS AND TYPICAL DARTS. DROP NO. 4, 28.4.82 AND DROP NO. 5, 29.4.82)

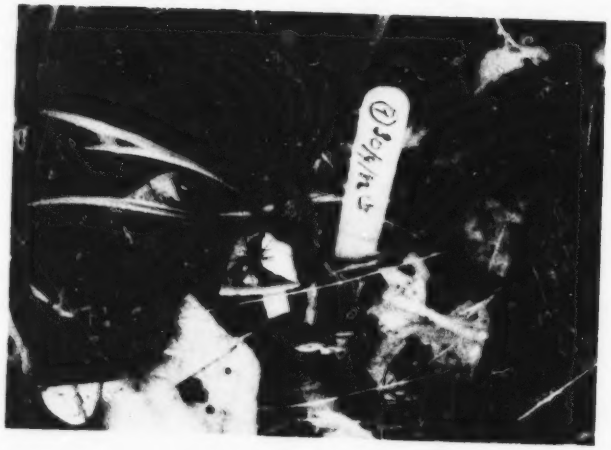
(a) DROP ZONE (PHOTO 30.4.82)

(c) DART A (PHOTO 3.5.82)

(b) DROP ZONE (PHOTO 9.7.82)

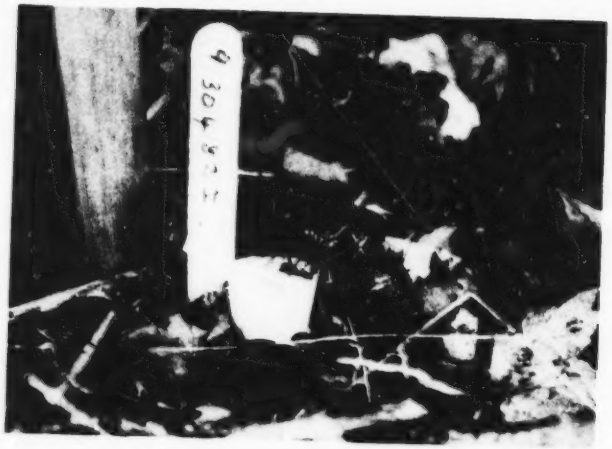
(d) DART A (PHOTO 14.10.82)

FIG. 16: KEMPTVILLE SITE ③ . SITE CHARACTERISTICS AND TYPICAL DARTS.
DROP NO. 9, 30.4.82



(a) DROP NO. 9. DART G (PHOTO 14.10.82)

(c) DROP NO. 10. DART C (PHOTO 14.10.82)



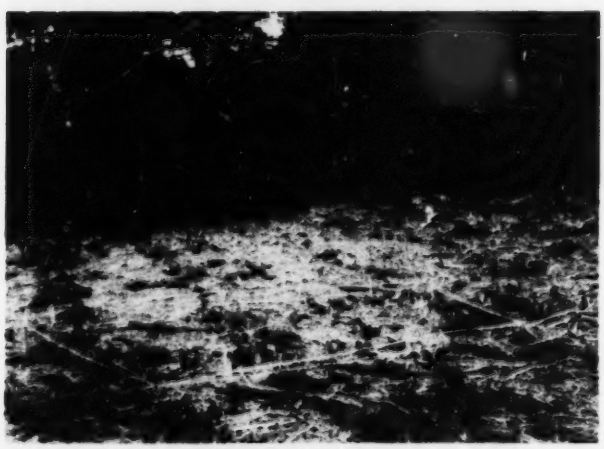
(b) DROP NO. 9. DART H (PHOTO 14.10.82)

(d) DROP NO. 7. DART A (PHOTO 14.10.82)

FIG. 17: KEMPTVILLE SITE ③ . EXAMPLES OF JACK PINE SURVIVAL.
DROP NO. 7, 29.4.82; NO. 9, 30.4.82 AND NO. 10, 3.5.82

(a) DROP ZONE (PHOTO 4.5.82)

(b) TYPICAL DARTS (PHOTO 7.5.82)



(c) DROP ZONE (PHOTO 20.10.82)

FIG. 18: PETAWAWA SITE ③ . SITE CHARACTERISTICS AND TYPICAL DARTS. DROP NO. 13, 4.5.82; NO. 18, 7.5.82 AND NO. 20, 12.5.82

(a) DROP NO. 13. DART B (PHOTO 24.6.82)

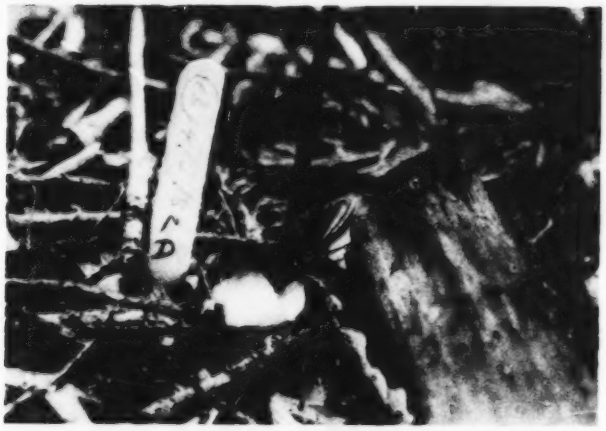
(c) DROP NO. 20. DART A (PHOTO 13.7.82)

(b) DROP NO. 13. DART B (PHOTO 20.10.82)

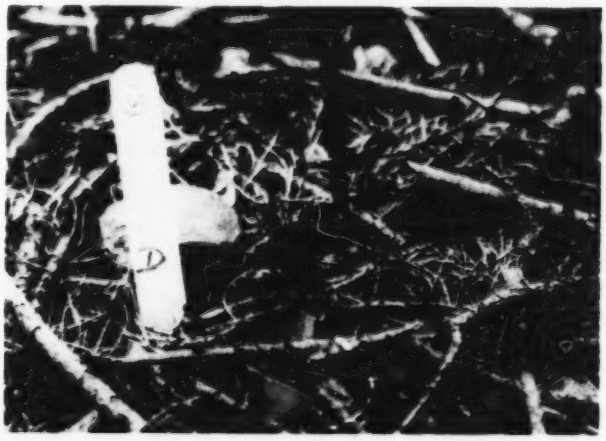
(d) DROP NO. 20. DART A (PHOTO 20.10.82)

FIG. 19: PETAWAWA SITE ③ . EXAMPLES OF JACK PINE GERMINATION AND SURVIVAL. DROP NO. 13, 4.5.82 AND NO. 20, 12.5.82

(a) DROP NO. 13. DART A (PHOTO 17.9.82)



(b) DROP NO. 13. DART D (PHOTO 20.10.82)



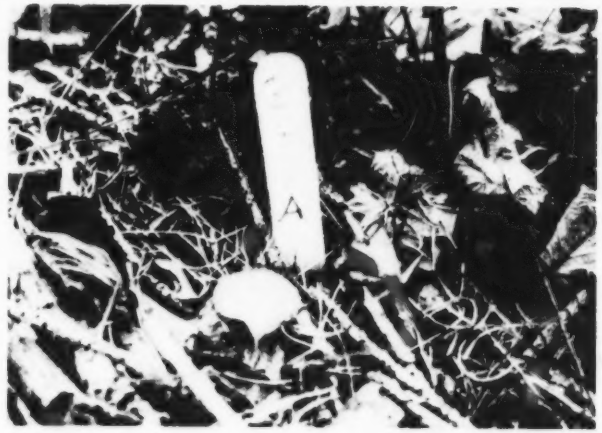
(c) DROP NO. 18. DART D (PHOTO 20.10.82)

FIG. 20: PETAWAWA SITE ③ . FURTHER EXAMPLES OF JACK PINE SURVIVAL. DROP NO. 13, 4.5.82 AND NO. 18, 7.5.82

(a) DROP NO. 15. DART A (PHOTO 2.7.82)

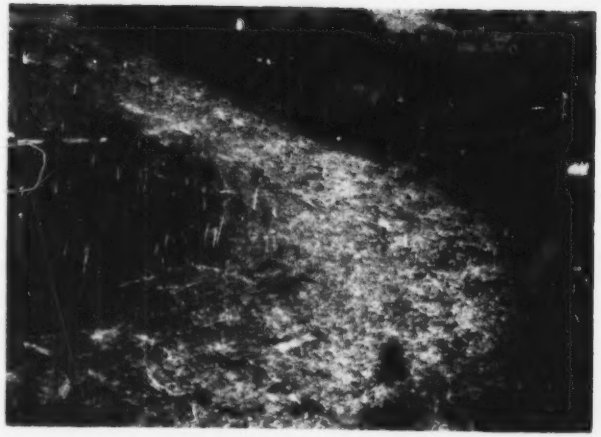
(c) DROP NO. 14. DART A (PHOTO 13.7.82)

(b) DROP NO. 15. DART A (PHOTO 20.10.82)



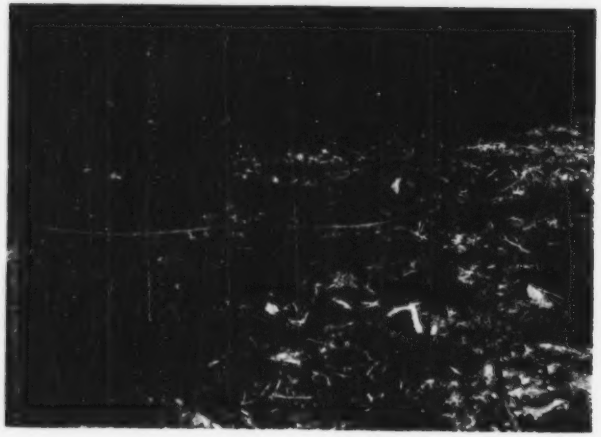
(d) DROP NO. 14. DART A (PHOTO 20.10.82)

FIG. 21: PETAWAWA SITE ③ . EXAMPLES OF WHITE PINE GERMINATION AND SURVIVAL. DROP NO. 14, 5.5.82 AND NO. 15, 5.5.82



(a) DROP ZONE (PHOTO 30.6.82)

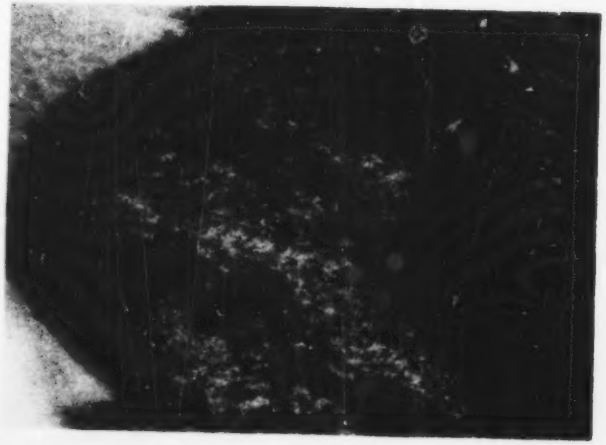
(c) DROP NO. 51, DART B (PHOTO 22.10.82)



(b) DROP ZONE (PHOTO 14.6.82)

(d) DROP NO. 51, DART E (PHOTO 22.10.82)

FIG. 22: MT. LAURIER SITE ② . SITE CHARACTERISTICS AND EXAMPLES OF JACK PINE SURVIVAL. DROP NO. 51, 14.6.82



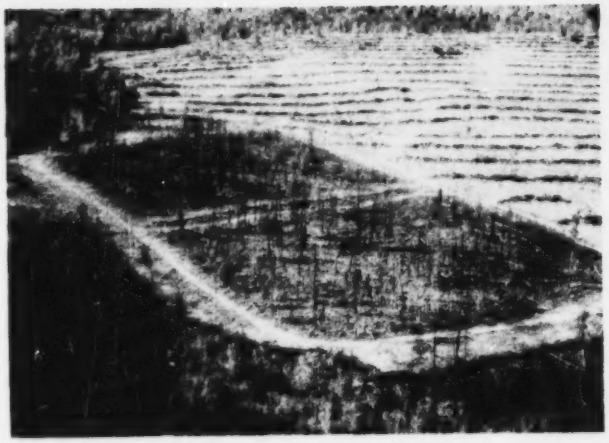
(a) DROP ZONE (PHOTO 30.6.82)

(c) SOIL CROSS-SECTION SHOWING ORGANIC LAYER (PHOTO 17.6.82)

(b) DROP ZONE (PHOTO 30.6.82)

(d) DROP NO. 57. DART C (PHOTO 22.10.82)

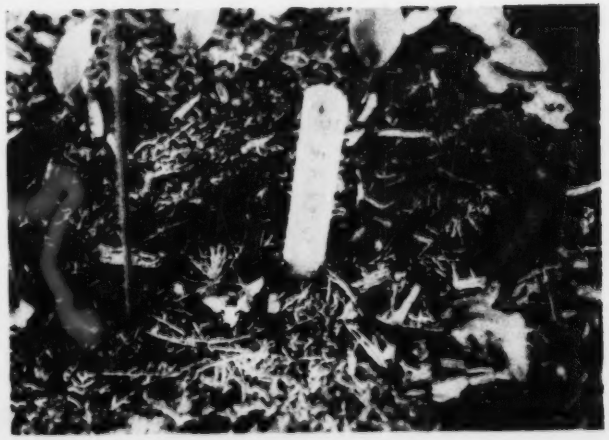
FIG. 23: MT. LAURIER SITE ③ . SITE CHARACTERISTICS AND EXAMPLE OF WHITE PINE SURVIVAL. DROP NO. 57, 30.6.82)



(a) DROP ZONE (PHOTO 3.6.82)

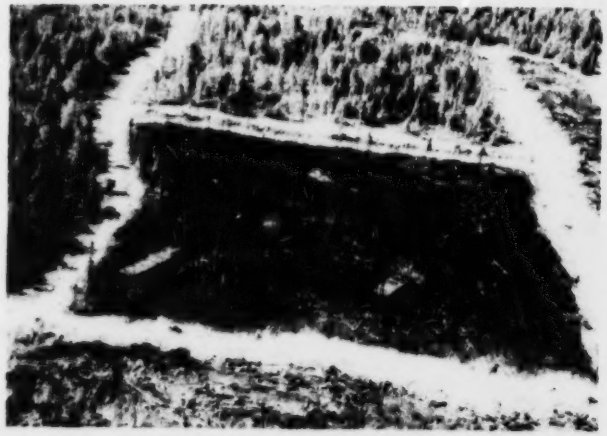
(c) DROP ZONE (PHOTO 26.8.82)

(b) DROP ZONE (PHOTO 26.8.82)



(d) DROP NO. 49. DART C (PHOTO 26.8.82)

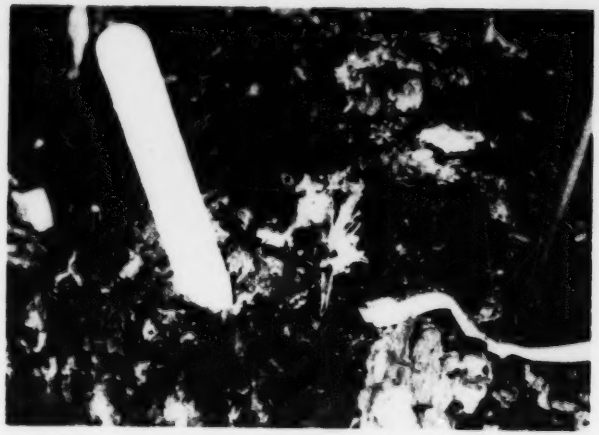
FIG. 24: AUBREY FALLS AREA SITE Ⓕ (1981 BURN). SITE CHARACTERISTICS AND EXAMPLE OF JACK PINE SURVIVAL. DROP NO. 49, 5.6.82



(a) DROP ZONE (PHOTO 3.6.82)

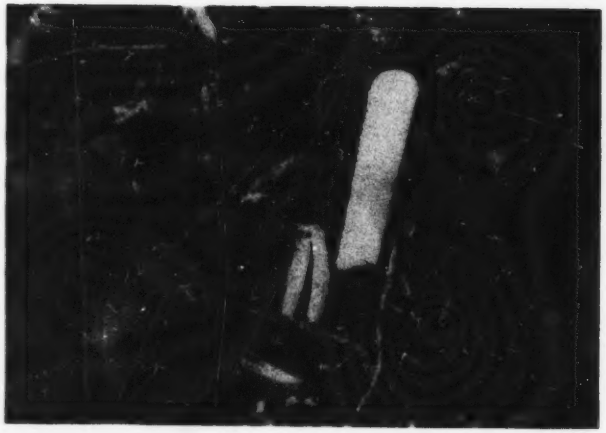
(c) TYPICAL DARTS (PHOTO 26.8.82)

(b) DROP ZONE (PHOTO 3.6.82)



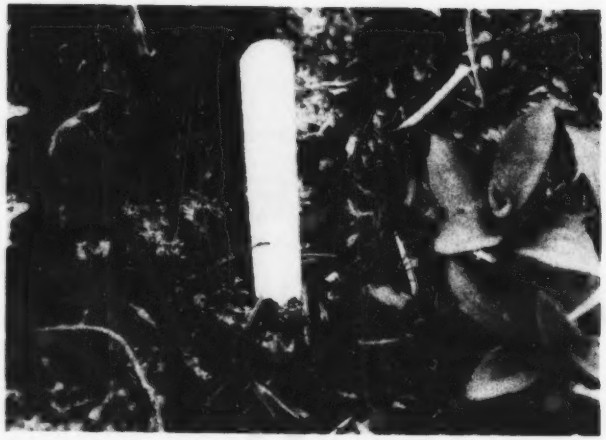
(d) EXAMPLE OF SURVIVING JACK PINE (PHOTO 26.8.82)

FIG. 25: AUBREY FALLS AREA SITE Ⓐ (1982 BURN). SITE CHARACTERISTICS AND EXAMPLE OF JACK PINE SURVIVAL. DROP NO. 35, 3.6.82.

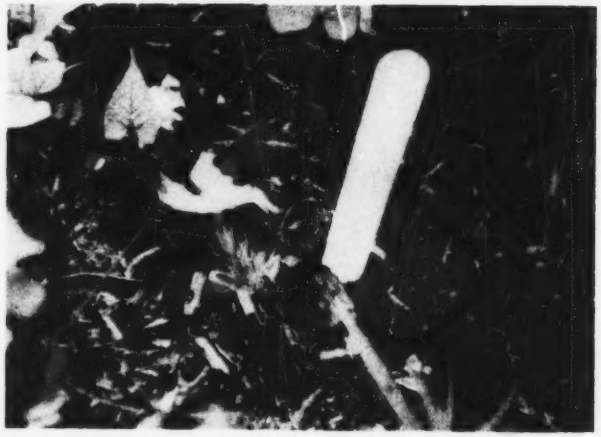


(a) EXAMPLE A (PHOTO 26.8.82)

(c) EXAMPLE C (PHOTO 26.8.82)



(b) EXAMPLE B (PHOTO 26.8.82)



(d) EXAMPLE D (PHOTO 26.8.82)

FIG. 26: AUBREY FALLS AREA SITE Ⓐ (1982 BURN). TYPICAL EXAMPLES OF JACK PINE SURVIVAL IN CONTROL-PLOTS. DARTS PLANTED MANUALLY 15.6.82

(a) SITE Ⓒ, (SCARIFIED). (PHOTO 3.6.82)

(b) SITE Ⓑ, (UNSCARIFIED). (PHOTO 3.6.82)

(c) SITE Ⓔ, (RESIDUAL TREES). (PHOTO 4.6.82)

(d) AUXILIARY SITE, (RESIDUAL TREES). (PHOTO 4.6.82)

FIG. 27: AUBREY FALLS AREA. ADDITIONAL SITES IN JOINT GLFRC/NRC PROGRAM

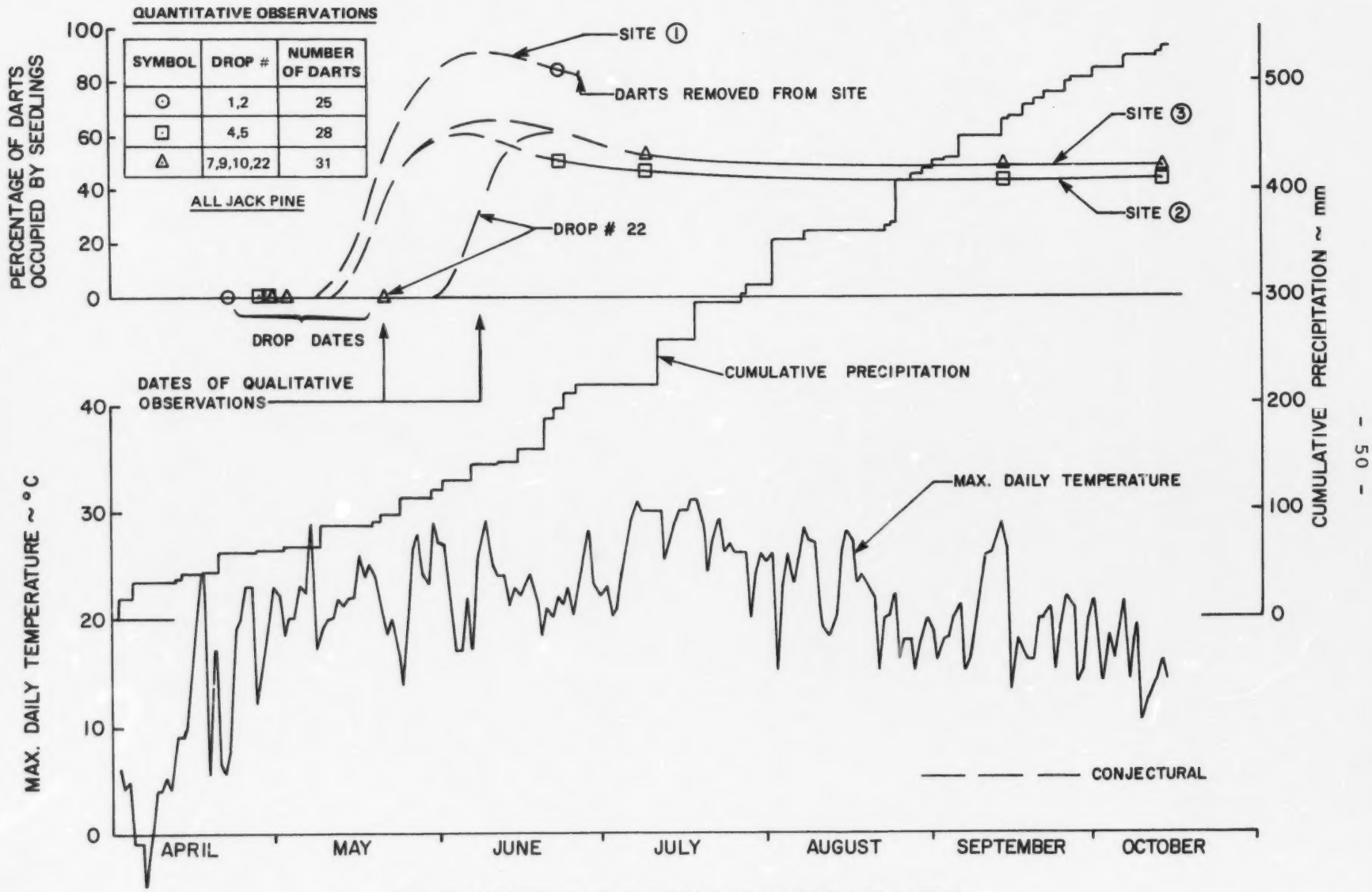


FIG. 28: KEMPTVILLE. SURVIVAL IN CANDIDATE DARTS

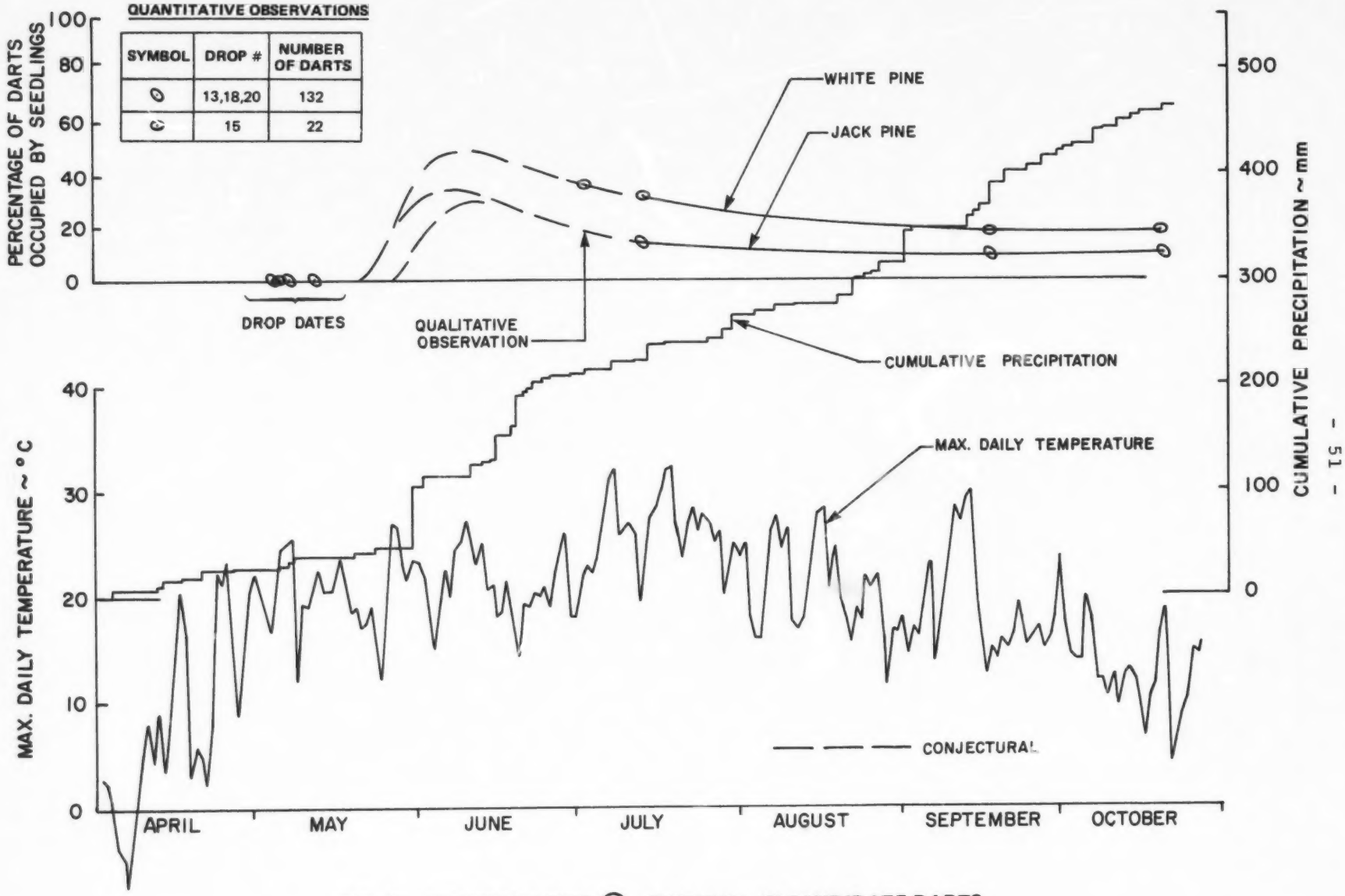


FIG. 29: PETAWAWA SITE ③ . SURVIVAL IN CANDIDATE DARTS

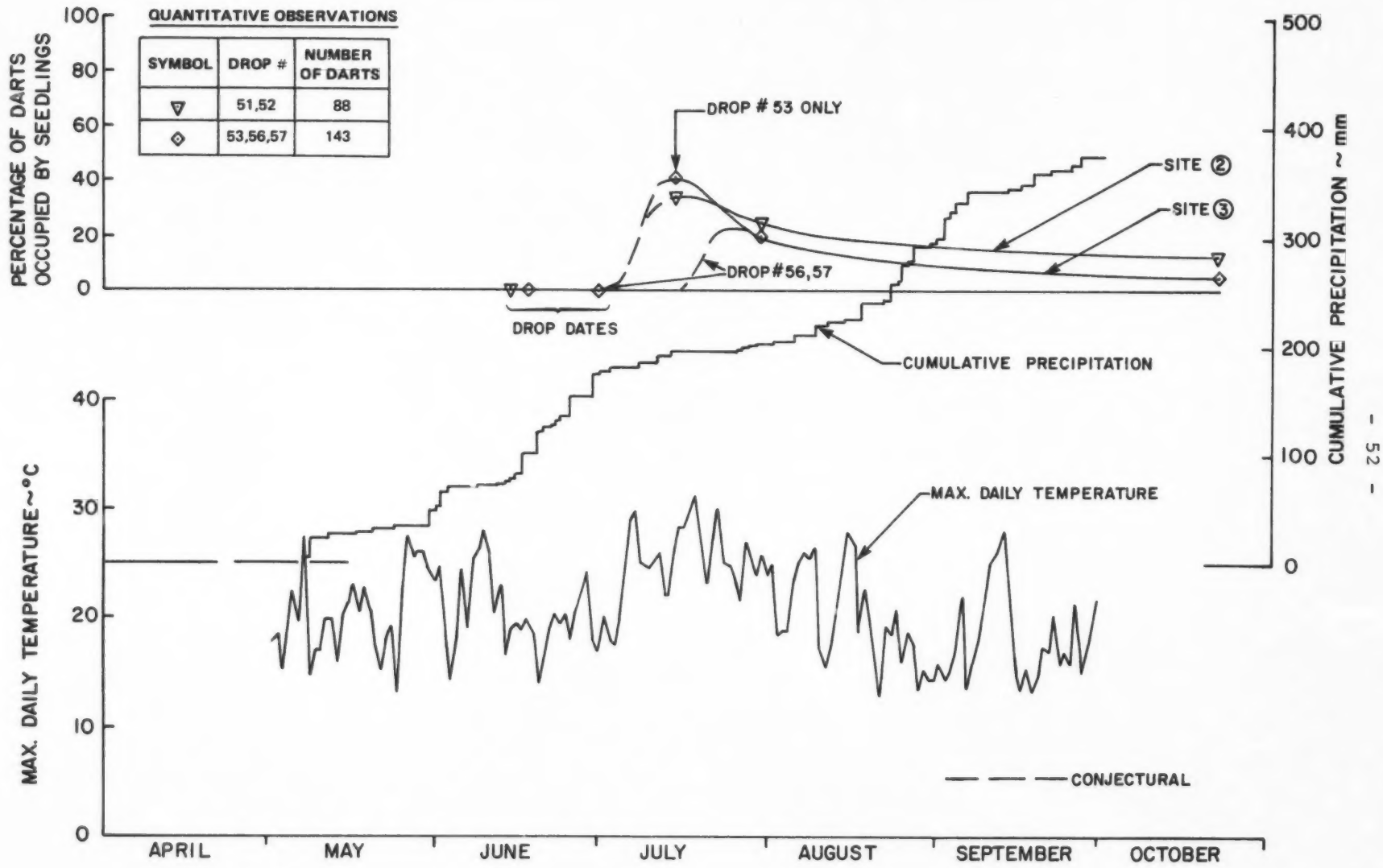


FIG. 30: MT. LAURIER. SURVIVAL IN CANDIATE DARTS

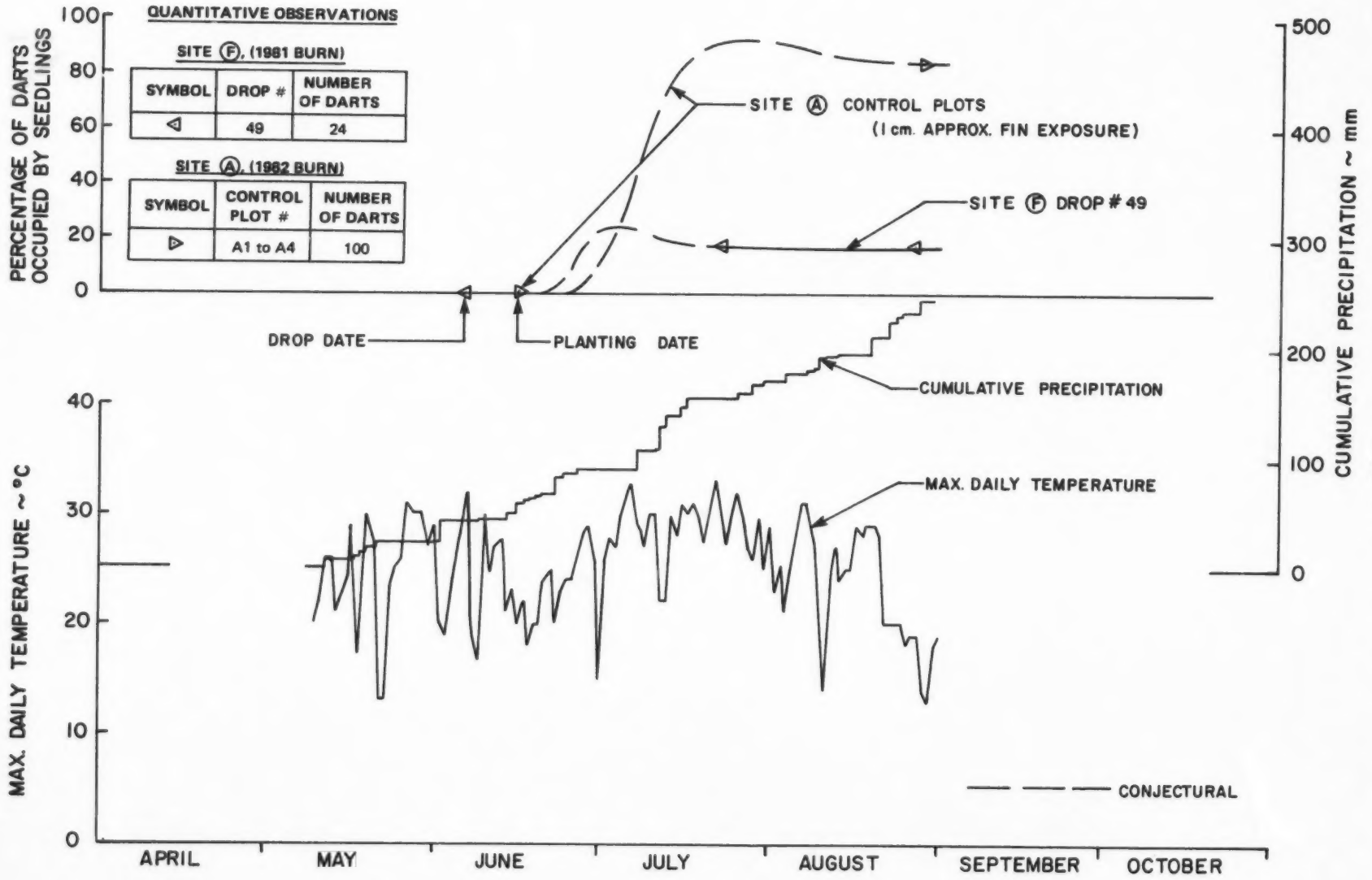


FIG. 31: AUBREY FALLS BURN SITES. SURVIVAL IN CANDIDATE DARTS

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4 Exploratory Field Investigation of Ground Penetration by Aerial Planting-Darts and Subsequent Germinant Survival

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1. Aeronautics in forestry
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SUMMARY/SOMMAIRE

The ability of aerial planting-darts to penetrate the ground and the subsequent survival of germinants have been investigated through airdrop tests conducted at various dissimilar sites.

The results indicate that there is a range of penetration within which darts may be considered as suitable candidates for the establishment of seedlings. Given some discretion in the selection of sites for aerial planting, it now appears reasonable to expect at least half the darts to achieve penetration within this range. The ultimate success, in terms of darts occupied by at least one surviving seedling, will then depend upon additional factors such as the depth of the mineral soil horizon below the ground surface, the presence of vegetation, the time of year and the prevailing weather.

Vigorous seedlings have been established by air-drops at some sites. Overall success rates are not, as yet, adequate, but the results have demonstrated the potential of the aerial planting technique and indicated some of the most promising avenues for further investigation and testing.

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